Master Thesis

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"Distributed geographical information for peacekeeping"

A case study for the United Nations/African Union Hybrid Mission in Darfur, UNAMID

submitted by

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Disclaimer

Though this thesis has been initiated to be adopted as a groundwork infrastructure to record security incidents for the UNAMID peacekeeping mission, it does not reflect any official approval or opinion of the United Nations or its affiliate organisations or bodies at the time of submission. The views, ideas and conclusions expressed in this thesis are those of the author and do not represent United Nations policies or endorsements.

Furthermore, the data used for the implementation of the technological application do not claim to be accurate and have been predominantly used to substantiate the application for visual purposes. Under no circumstances should there any conclusions be drawn based on the data displayed hereafter.

Statement of Scientific Conduct

I hereby declare that this master thesis was written without the help of a third party and without the use of sources other than the ones cited in this paper. In addition, the thesis is submitted for the first time and has not been submitted to any other institution for assessment. I certify that all thoughts in this paper that are not my own writing, including images, figures and tables, are appropriately referenced.

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Abstract

Geographical information is like any form of intelligence a determining factor of success in peacekeeping missions. These missions are run in hostile, unknown and unpredictable environments. Accuracy, timeliness and availability of geoinformation can help to gain significant rewards in newly set up operations. The provision of geographical information increases security and defense capabilities for the mission and lowers stress on resources through tightening business processes.

This paper will employ an application to overcome the security deficiencies of the United Nations / African Union Hybrid Mission in Darfur (UNAMID). UNAMID is today's largest UN peacekeeping mission and was set up in 2007 to restore the rule of law, protect civilians and supervise the fragile Darfur Peace Agreement (DPA). The agreement resulted from a long history of war and conflict in the region, leading to genocide, war crimes and crimes against humanity indictments against leading officials of the national government in Sudan.

The application will implement an infrastructure to record security incidents of the peace mission. The setting of UNAMID with remote, spatially dispersed and inaccessible UN locations and military teamsites necessitates an infrastructure that disseminates geographical information using a distributed approach. To share geodata, the focus will be on an intranet-based application to visualize, map and edit all security incidents. The security incidence reporting system (SIRS) uses the UN's central database technology and invokes an open source architecture to allow for interoperable information sharing.

Interoperability is ensured by Open Geospatial Consortium (OGC) standards, namely the Web Map Service (WMS) and the Web Feature Service (WFS). These standards, developed by the OpenGIS© community, communicate through specified protocols and have grown to be *de facto* standards for sharing geographical information on the World Wide Web. GeoServer, OpenLayers and GeoExt are further utilized to substantiate and complete the application. Together, they reap huge benefits for providing easy accessible, up-to-date and enriched geoinformational content. The result of lowered barriers to geoinformation

improves its quality in two ways. Exogenously, freely available and premium geocontent may be seamlessly integrated. Endogenously, increased user interaction augments the data of the core application by partaking more relevant users and information holders. By taking an informational leap forward, security is concurrently improved for peacekeeping operations.

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Abstract (Deutsch)

Geographische Informationen sind wie alle Formen der Informationsgewinnung ein bestimmender Faktor für den Erfolg von Missionen zur Friedenswahrung (peacekeeping missions). Diese Missionen operieren in feindlichen, unbekannten und schwer überschaubaren Umgebungen. Genauigkeit, Aktualität und Verfügbarkeit von Geoinformationen können helfen, diese beeinträchtigenden Faktoren zu verringern. Die Bereitstellung von geographischen Informationen erhöht nicht nur Primärziele wie Sicherheit und Verteidigungskraft, sondern reduziert auch Missionskosten durch straffere Geschäftsprozesse.

Die United Nations / African Union Hybridmission in Darfur, UNAMID, wurde im Jahr 2007 errichtet, um in der Region die Zivilbevölkerung zu schützen, die Rechtsstaatlichkeit wiederherzustellen und die brüchige Darfur Friedensvereinbarung (DPA) zu überwachen. Dieser Friedensvertrag stand am Ende einer langen Periode von Kriegen und Konflikten, die in internationale Ächtung und Anklage gegen führende Politiker der sudanesischen Regierung wegen Völkermords, Kriegsverbrechen und Verbrechen gegen die Menschlichkeit mündeten.

Um die Informationsdefizite von UNAMID zu verbessern, wird ein System zur Erfassung von sicherheitsrelevanten Vorfällen implementiert (SIRS). Die starke räumliche Dispersion der militärischen Standorte und UN Basen erfordert eine entsprechend angepasste technische Infrastruktur, die in der Lage ist, die geographischen Informationen schnell und effizient in entfernte Regionen zu übermitteln. Aus diesem Grund wird das System, das sicherheitsrelevante Vorfälle visualisiert und deren Daten administriert, auf das bestehende Intranet aufgesetzt. Die Applikation nutzt hierfür die bestehende zentrale Datenbanktechnologie und erweitert die Anwendung um interoperable Open-Source Standards.

Interoperabilität wird durch Standards des Open Geospatial Consortium (OGC) gewährleistet. SIRS implementiert den Web Map Service (WMS), den Web Feature Service (WFS) und deren Substandards. Diese Komponenten, entwickelt von der

OpenGIS© Gemeinde, kommunizieren mittels standardisierter Protokolle und sind zu *de facto* Standards in der Verteilung geographischer Informationen über das Internet geworden. GeoServer, OpenLayers und GeoExt sind weitere Softwarekomponenten, die für die Funktionalität von SIRS integriert und programmiert werden. Zusammen stellen sie große Vorteile für den Austausch von Daten mit geographischem Bezug bereit. Standardisierungen vermindern geoinformatische Barrieren und führen zu einer Qualitätsverbesserung in zweierlei Weise. Exogene, frei erhältliche und in der Qualität oftmals überlegene Geodaten können friktionslos in das System eingebunden werden. Endogen verbessert die Applikation die Kerndaten der Sicherheitsvorfälle durch verstärkte Partizipation der Entscheidungs- und Informationsträger. Diese Informations-verbesserungen wirken sich positiv auf die Sicherheit der Friedensmission aus.

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Abbreviations

API	- Application Programming Interface
AU	- African Union
CGI	- Common Gateway Interface
CFGISA	- Common Framework of Geographic Information System Architecture
DPA	- Darfur Peace Agreement
DPKO	- Department of Peacekeeping Operations
EPSG	- European Petroleum Survey Group
GI	- Geographical Information
GIS	- Geographic Information Systems
GML	- Geographical Markup Language
HMI	- Human-Machine Interface
HTTP	- Hypertext Transfer Protocol
ICC	- International Criminal Court
IDP	- Internally Displaced People
ISS	- Integrated Support Services (high-level section of the United Nations organizational structure of peacekeeping operations)
JEM	- Justice and Equality Movement; a Darfur rebel group
JMAC	- Joint Mission Analysis Center (Peacekeeping Unit)
JOC	- Joint Operations Center (Peacekeeping Unit)
MIME	- Multipurpose Internet Mail Extensions
NGO	- Non-governmental organisation
NIF	- National Islamic Front; a term for the national Sudanese government since 1989
OGC	- Open Geospatial Consortium
PL/pgSQL	- Procedural Language/Postgres Structured Query Language
RDBMS	- Relational Database Management System
REST	- Representational State Transfer; a form of internet communication
SIOC	- Security Information and Operations Center (Peacekeeping Unit)
SIRS	- Security Incident Reporting System; The technological application of this thesis

SLD   - Style Layer Descriptor

SLA   - Sudan Liberation Army; a Darfur rebel group

SPLA   - Sudan People's Liberation Army; South Sudan's Christian rebel Group

SQL   - Structured Query Language

SRS   - Spatial Reference System

TCP   - Transmission Control Protocol

UN   - United Nations

UNAMID   - United Nations/African Mission Hybrid Mission in Darfur

UNDPKO   - United Nations Department of Peacekeeping Operations

UNGIWG   - United Nations Geographical Information Working Group

URI   - Uniform Resource Identifier

URL   - Uniform Resource Locator

WCS   - Web Coverage Service

WMS   - Web Map Service

WFS   - Web Feature Service

WFS-T   - Transactional Web Feature Service; OGC standard to edit geodata

XML   - Extensible Markup Language

1 Introduction

The main focus of this thesis is to analyse the role of geographical information in peacekeeping operations with a subsequent technological implementation of a security incidence reporting system (SIRS). To accomplish these tasks, the following objectives are formulated.

1.1 Objectives

- Provide an introduction of Darfur and UNAMID
- Evaluate the use of geographical information for peacekeeping operations
- Implement an implementation that maintains the security incidents of the peacekeeping mission

The technological features of the security application are required to perform the following:

- Ability to retrieve geodata from multiple locations throughout the mission
- Provide up-to-date, accurate and information-rich maps
- Overlay content-specific geodata that can be displayed and more importantly, queried
- Edit geodata and write changes back to the database
- Ensure appropriate security measures and restrict access to (sensitive) information

To answer these aims, the structure of the thesis is divided into two lead chapters. *Chapter 2* provides an introduction of the region Darfur by predominantly focusing on its recent history. It will explain why the region turned into one of the wariest corners of the world. In order to shed light on these developments, a closer look at the origins of the conflict is

needed to understand why an involvement of the international community was indispensable.

The second part of this chapter introduces the role of UNAMID in settling the conflict and establishing the foundation for an enduring peace. Its main purpose of protecting civilians, supervise the ceasefire agreement and restore the rule of law is further elaborated to legitimise its operation.

The latter part of *Chapter 2* highlights the role of geographical information in peacekeeping operations. Such information not only has huge potential in increasing security for staff and mission objectives but can also bring down operational expenses.

Chapter 3 deals with the technological implementation of the incidence reporting system. The opening chapters will argue for a distributed client-server model since it provides manifold advantages to disseminate geographical information by capitalising on the existing intranet infrastructure and the implementation of widely adopted standards.

The development of the web based application in *Chapter 3.6* will focus on the Open Geospatial Consortium standards WMS and WFS, along with its subsidiary components. They provide the key mechanism for the server-client communication. These standards are powerful tools to propagate information with a geographical content, whereby WMS transmit rendered images and WFS deliver the "source" data. The former is an efficient tool to visualise data, whereas the latter is needed to edit the database. Both web services will be supplied by GeoServer, extending a HTTP-server to utilize geospatial capabilities.

Finally, OpenLayers and GeoExt are introduced in the latter parts of the development chapter. These JavaScript libraries are used to enrich the SIRS infrastructure. OpenLayers combines data from various sources to increase the value of the mapping application by retrieving premium geocontent regardless of origin. GeoExt is a tool to increase the visual appeal of the application and enhance the user experience. User acceptance is perceived to be a critical facet for the success of the application.

1.2   Non-Objectives

All technical chapters in this thesis have a specific focus on geospatial content. As such, it completely neglects other domains that were needed for its accomplishment like HTML-web design, cascading stylesheets (CSS), Common Gateway Interface (CGI), database configurations, e.g. SQL, PL/pgSQL (Postgres' procedural SQL language), shp2sql, or several other relevant information technology requirements. These are integral part of the application but are omitted for coherence and constraint limits.

Furthermore, this thesis presents its results using a PostGIS database clone of the UN's ArcSDE© / MS SQL Server© database. Though, the application has been tested and fully works with its ArcSDE© technology (as witnessed by the ArcSDE© data's full integration in "*Appendix 5GetCapabilites document for SIRS*", p. 105), PostGIS had the tremendous advantage to be locally available. This was quintessential in the system's development as well as the thesis' writing to use the valuable time offline and outside UN premises.

The central purpose of the system is to visualize and maintain UNAMID's security incidents. Such functionality provides valuable insights about geospatial phenomena. Nevertheless, in absence of filtering operations such as date or sector queries, the system will be most successful in operational aspects and its use for higher-level analyses delimited. For this reason, the system should only be seen as a starting point for further development to accommodate more query, geoprocessing and presentation capabilities.

2 Literature Review

Chapter 2 embeds the SIRS application in its theoretical setting. A closer look at the UNAMID peacekeeping operation and for what history it has been set up as well as the role of geoinformation in UNAMID helps to put the technological application into its perspective.

2.1 History of Darfur

In terms of size, Sudan is Africa's biggest country with 2,505,813 km² (CIA Homepage 2011). The country's geography varies from the mainly arid Sahara in the north to tropical rainforests in its southern part. The amount of precipitation linearly increases in a southerly direction. A dominant influence in the country's geography is exerted by the river Nile, which contrasts the desert conditions in a stretch of fertile land as one leaves the luscious forests of the South.

In addition to the country's geographical divides, it also exposes ethnical and religious segregation, which have been cause for a mushrooming number of conflicts, wars and civil strives on numerous fronts. Today, it has not only violent clashes with its Christian denomination in the South but also interreligious clashes among the Islamic religion, and here in particular with Darfurian tribes. The ethnic composition of Darfur is diversified but the dominant population is the Fur tribe giving it its name which translates to "land of the Fur".

Darfur is Sudan's most western province. It is an extremely hot and dry region where the Sahara is pressing southwards from Libya. Topographically, Darfur is dominated by Jabal Marra, an extinct volcanic range with summits reaching almost 3.000 metres. The mountain range splits Darfur in distinct ecological and ethnic territories. *Figure 1* illustrates a map of Darfur including UN bases and refugee camps.

Figure 1   **Map of Darfur**
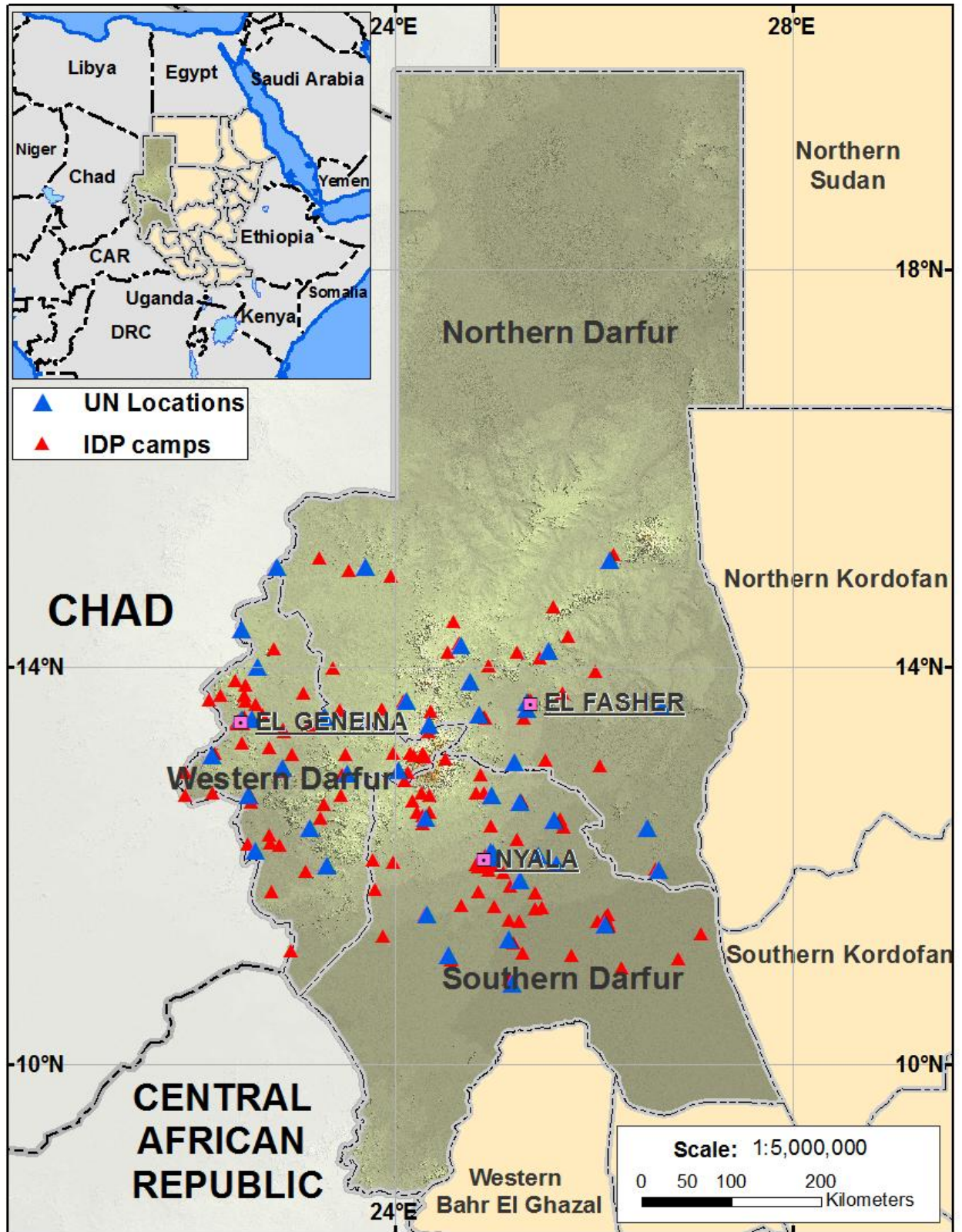
The mountains provide fertile land at its western flanks because of increased precipitation. The mountain range has always had a cultural importance, too, dividing the region into three main ways of life according to rainfall boundaries. The north was dominated by camel nomadism, the west and south by rainfed agriculture and the east by cattle nomadism (O'Fahey 2008; p. 18). At the same time, Jabal Marra has also only been a modestly permissible ethnic boundary in the past, separating the Arabic influence of the East and North from the African tribes on its western and southern sides. This line puts the mountains in the centre of many historical events from refuges for sultans to recent rebel hide-outs.

Historically, Darfur had been an independent sultanate from approximately the fourteenth century until 1916. The days of the sultanate had been numbered with a growing Turco-Egyptian influence and their invasion in 1874. In 1916 it was annexed by the Anglo-Egyptian Condominium, which ruled Darfur as part of Sudan for another forty years until Sudan's independence in 1956. The main interest of the colonial rule was to keep the peace in the region and leave it to its own devices as best as possible (Flint et al. 2005; p. 12). The entente adopted a rule of benign colonial neglect in which Darfur was ruled by an informal system of tribal rule.

Its landlocked location always isolated Darfur from most parts of Africa and it was transited by only a few traders between the sultanates in the West, Egypt in the North and a few countries in the South for ivory and slaves (Prunier 2007; p. 2). This should not portray a lively expanse since the region, by and large, is and always has been an extraordinarily remote place that has come into the international limelight only because of its gloomy history since the outbreak of war in 2003. The region had struggled with a dismal history up until then, too. However, it was this particular war, from 2003 - 2005, when the term genocide was first brought to the attention of the international media.

At first, the media primarily focused on a humanitarian crisis, thus avoiding a blame of the aggressors. It has also long been debated whether the Darfur conflict measured up to a genocide or not, but it complies with both prerequisites; its definition and the need of

deliberate intent. The 1948 International Convention on the Prevention and Punishment of Crimes of Genocide defines genocide as "*deliberately inflicting on the group conditions of life calculated to bring about its physical destruction in whole or in part*" (UN Website 2011). Intent is a much harder juridical onus to be brought, but the evidence seems overwhelming. Both assumptions are elaborated in adjacent chapters.

At the very source and this might also be at the risk of oversimplification, the Darfur conflict is an uprising of the Afro-American ethnic groups against the Arabic central government in Khartoum, Sudan's dominant capital. The term Sudan is borrowed from medieval Arab geographers, referring to "beled as-Sudan" or "Land of the Blacks", historically replicating an expanding influence of the Turco-Egyptian occupation towards its southern neighbours with Arabic values in the nineteenth century (Prunier 2007; p. 15).

Colonial disregard developed in a culminating under-development of education, health and justice services as well as its economy. So severe was the neglect of Darfur that at the end of the Anglo-Egyptian rule in the mid-1950s only an estimated 5-6% of all Sudan's investment reached Darfur, already bearing the seeds of future conflicts (Prunier 2007; p. 33). Sudan's independence in 1956 marked an already deep political divide between a pro-Egyptian dominance of its capital Khartoum and an anti-Egyptian resentment of Darfur.

The anti-Khartoum alliance of Darfurians was not nurtured for centuries but rather a reaction to a series of clumsy national government policies and severe suppression. To portray Darfur as an aggressor against the central government would be an unbalanced view. On the contrary, most Darfurians were far from resenting Arab traditions, spoke Arabic and had adopted Arabic cultural norms (Daly 2007; p. 267). It might rather be seen as a self-defence reaction to increased oppression and this has indeed often been the root of such uprisings.

After independence, the dominant north with its national government in Khartoum exacerbated the oppressive trend and deprived all other regions, and especially Darfur, from most benefits. Modern post-colonial history consolidated the primary focus on Arabism

through numerous military, foreign and economic ties with Egypt and Libya, strengthening a Muslim nationalist rhetoric (Daly 2007, p. 10).[1] This is further reflected in the vast majority of government positions held by three Arab tribes, the Shayqiyya, Ja'aliyyin and Danagla tribes, which only represented 5.4% of the entire diverse ethnicity of Sudan in the year 2000 (Flint et al. 2005; p. 18). The appearance of a Black Book in the same year triggered a series of events by revealing that Darfur's poverty was not a result of its remoteness or climate but a result of Khartoum's policies to keep the region poor (Daly 2007; p. 276). The book dispersed rapidly and initiated the Justice and Equality Movement (JEM), which is today Darfur's biggest rebel movement.

The ethnic division finally slipped out of control through the political division of Darfur into three states, turning the non-Arab Furs into a minority in all three of them (*Figure 1*) (Daly 2007; p. 262). Furthermore, the government's inaction as well as its liaison with Arab tribes and militias, *de jure* forfeiting its neutrality, led to rising civil disobedience coupled with small-scale self-defence and resistance. The first rebel movements were reactive and were launched for a variety of external and internal life-threatening reasons.

Mutually reinforcing factors to the political developments were the constantly present "historical trio" of drought, famine and disease (Daly 2007; p. 139). The lack of development and relief operations intensified such catastrophic disasters and culminated in the famines of 1973 and 1984. The 1984 famine alone left 100.000 people dead (Prunier 2007; p. 56). Another crucial aggravation was the crisis denial of the then government. The government denied the violence, blamed it on rebel propaganda and war-mongering neighbouring regimes, belittled the affair as an outright exaggeration by Western media or attempted to entirely ignore the problem. Outside interference was dismissed for reasons of patronisation, vanity or conspiracies to bring down the regime. In October 1990 the government's Economic Affairs Committee issued the statement "We will never accept any food aid, even if famine is declared (Daly 2007, p. 261).

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[1] These agreements entailed the Economic Integration Agreement with Egypt in 1969, the Tripoli Charter in 1969, and the Tripartite Economic Agreement in 1970

To add insult to injury, Darfur was dragged into regional conflicts between Chad, Libya and Southern Sudan, all having their own belligerent agenda. Libya was concerned with a Chad conflict that also opened a Darfur front. In this conflict thousands of civilian refugees and Chadian forces had settled across the border in Darfur. The influx increased the already high pressure on scarce resources, leading to overgrazing, deforestation, soil exhaustion and desertification. Darfurian voices demanded a removal of these "displaced aliens" (Daly 2007; p. 229). Ethnic tension and raids were on the rise. The weapons needed for the violence were easy to get. Darfur was encircled by conflicts and flooded with inexpensive hand arms such as the AK-47 (Kalashnikovs), which are still widely seen in Darfur's everyday life.

Throughout this time, Khartoum had hegemonic interests towards its southern Christian part. This twenty-one year fought war, i.e. First Sudanese Civil War (1955-1972) and a second civil war from 1983-1989 cost even more death, an estimated two million, and was never taken up by the UN Security Council (US Department of State Website 2011). The North-South conflict had always received the main attention beyond the borders of Sudan. The second front of Darfur received recognition only a few years later.

All these fronts created an atmosphere of violence and ethnic hatred in which Darfur got enclosed and actively involved. The indigenous Darfurian tribes were conscripted and had to take part in these conflicts. The 1980's and 1990's were a dismal period for Darfur with heavy fighting, such as the Arab-Fur war between 1987-1989, and an enormous number of casualties involving Chadian, Libyan and Sudanese insurgencies. The term Arab-Fur war already carries in its title the connotation of a racial war, which magnified in the years 2003-2005.

The battles at the end of the last millennium received little recognition because the killings were piecemeal and their nature more military. A certain level of violence was also considered to be normal in this region and played down as "tribal violence". It should not disguise the fact that during this period "scorched earth, massacre, pillage and rape were the norm" (Flint et al. 2005; p. 25).

"Darfur in the late 1990's was an increasingly marginalized, violent and frustrated place" (Prunier 2007; p. 81). It was marginalized because the Khartoum government did little to counteract early warning signs. The more moderate view is that the government was preoccupied to come to terms with its troublesome southern entanglement. This view is supported by a number of agreements in 2002 and 2003 between the government of Sudan and the Sudan People's Liberation Army (SPLA), the representation of the Christian South (Prunier 2007; p. 90).

The more extreme view, however, is that the government was buying time to prepare and initiate one "the world's worst humanitarian crisis"[2] and the Darfur genocide. Though there were a variety of negotiations and peace summits organised by the government (see next chapters), a lack of moderating influences and the dominant military wing in the government depicts a crueller picture. Daly (2007; p. 279) asserts the negotiations were only instigated to improve the government's public face, while at the same time Khartoum was arming the Janjaweed militia. The Janjaweed is a rough armed band of convicts, fugitives and desperadoes that existed since the late 1980s and which was of particular interest to Khartoum for its Arab descent (Prunier 2007; p. 97). They are the major perpetrator responsible for the atrocities against civilians and genocide in Darfur.

In the year 2003, Darfur and its rebel groups, among which the Justice and Equality Movement (JEM) and the Sudanese Liberation Army (SLA) are the biggest, as well as the government of Sudan had taken up their arms. By then, the riverine Khartoum administration, led by al-Bashir's National Islamic Front (NIF), adopted a military strategy to solve the conflict, involving the Janjaweed to conduct close combats. This became to be known as the NIF/Janjaweed Alliance. Musa Hilal, Janjaweed's leader, spelled out in a 2004 directive to "change the demography of Darfur and empty it of African tribes", clearly showing the aggression and ideological thoughts of Arab supremacy (Flint et al. 2005; p. 39). The political arena was powerless and after all half-hearted negotiations, like the *2002 Committee for Restoration of State Authority and Security in Darfur* or the *Fur Leadership*

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[2] Mukesh Kapila, UN representative in Khartoum, cited from Flint & Waal (2005;p.126)

Conference in August 2002, remained unsuccessful it became clear that a violent conflict was bound to happen.

The advent of fighting in the year 2003 began with rebel attacks against government positions, whereby the rebels at first won almost every encounter. In the middle months of 2003 the rebels prevailed over 34 out of 38 clashes (Flint et al. 2005; p. 101). These victories, however, were short-lived. The government soon realised that its stationary army was not a good match against the highly mobile rebels and adopted a number of strategies to gain the upper hand in what has already descended into an undeclared civil war. It was gradually fortifying its military infrastructures in Darfur in addition to supply the paramilitary Janjaweed with arms, artillery, military advisers and communication equipment (Flint et al. 2005; p. 102-103). The latter strategy soon turned the militia against civilians. The warfare turned into genocide.

While the fighting between the government and rebel groups continuously declined, the atrocities of the Janjaweed against civilians increased (Flint et al. 2005; p. 104). The normal cycle of combat began with aircrafts flying over villages and dropping bombs. These bombs were often nothing more than old oil drums stuffed with explosives and metal debris without any aiming mechanism. Hence they had not much of military use and were targeted at large areas as given by urban dwellings and villages. The second cycle was followed by combat helicopters that searched for still intact buildings with rockets and machine guns. Afterwards the Janjaweed militia moved in, alone or with government units, looted the place, raped women and children and killed everyone that could not run away, burnt the houses and left (Daly 2007; p. 283 & Prunier 2007; p. 100). The eyewitness accounts are plentiful and detail the unimaginable horrors:

"One young man who was the only survivor in his family, having saved his life by hiding under a dead mule, recounted how the attackers took a knife and cut [his] mother's throat and threw her into the well. Then they took [his] sister and began to rape her, one by one. [His] father was kneeling, crying and begging them for mercy. After that they killed [his] brother and finally [his] father. They threw all the bodies in the well" (Flint et al. 2005; p. 104).

Another eyewitness reports how in Bargai,

"a young mother who had just given birth to twins was killed with her legs tied to her neck, exposing her genitals. Her babies were thrown into a container of boiling water that had been brought for the birth" (Flint et al. 2005; p. 109).

These are just two of the sheer endless crimes that made the leader of the South African contingent of the African union say: "You believe there's an inherent goodness in people, but you see some of these villages and it shakes this belief". In another statement, the UN put forward a "nightmare of violence and abuse (Flint et al. 2005; p. 108-112). It also underpins why civilians have suffered most in this conflict and since the start of the war, atrocities against its own citizens have been widespread involving the murder of non-combatants and children, the rape of women and girls and the looting and destruction of villages. Large areas were ethnically cleansed. Low estimates from the U.S. State Department estimate 400 villages were completely destroyed, the UN puts forward it may have been up to 2000 (Daly 2007; p. 284, Flint et al. 2005; p. 112). Those who could run away or were left behind by the Janjaweed gathered in IDP camps, which were, perceived or real, more secure. Some 2.5 million people were forced from their homes and gather as internally displaced people (IDP) (UNAMID Website 2011). The IDP camps are scattered all around Darfur (*Figure 1, p. 5*).

The government of Sudan has always denied any involvement and condemned the Janjaweed actions. This, however, is implausible for numerous reasons. Firstly, air force bombardments could only be initiated simply because they were the only party with aerial military equipment. Secondly, eyewitness reports provide detailed information that the Janjaweed raided on camels and horses and the army was overlooking the attacks in its Land Cruisers. Thirdly, leaked army intelligence report instructions 'to kill anything that is alive' and orders of non-interference of Janjaweed attacks and impunity for all soldiers and militias involved. In September 2003, a British journalist intercepted the following radio conversation between an army commander and an Antonov pilot:

Commander: We've found people still in the village.
Pilot: Are they with us or against us?
Commander: They say they will work with us.
Pilot: They're liars. Don't trust them. Get rid of them.

Flint et al. (2005; p. 107) purport this conversation "needed authorization from the chief of staff's office in Khartoum, [making] nonsense of the government's insistence that it was not supporting Janjaweed operations". Fourthly, the government did everything it could to obstruct relief efforts, denying visa for international NGOs, suppressing, censoring and closing media institutions and using "starvation as a military strategy" (Flint et al. 2005; p. 112). The list extends to food aid being confiscated or impounded for being "genetically modified", in other cases drugs were held back for testing (Daly 2007; p. 286). Fifthly, investigations by regional and supranational organizations report genocidal activities and for this reason today's President Omar Al-Bashir, coming into office through a bloodless military coup in 1989, is sought for war crimes, crimes against humanity and genocide and is listed as a fugitive by the International Criminal Court (ICC). He is the first sitting president ever to be charged by the ICC and also the first person ever to be charged with genocide (Wikipedia 2011; Omar Al-Bashir).

It is hard to estimate how many people died in the conflict, but only for Darfur, the numbers are appalling. The most conservative forces, the government of Sudan, put this figure at 10.000. UN sources estimate 300.000 mostly innocent and unarmed people lost their lives. These numbers remain estimates and a true number between a continuously refuting central government and an ideologically exaggerating West is highly unlikely to ever be established, but taken into account that some humanitarian groups claim more than 500.000 deaths, the UN estimate seems to portray a better picture of what really happened. Furthermore, these estimates only account for violent deaths. The UN's top emergency relief official, Jan Egeland, approximates the number of deaths by malnutrition and diseases amounted to an additional 10,000 people in IDP camps for each month in the year 2004 alone. For the 18 months of fighting in 2003-2005, the reports estimate a total of another 200,000 victims (BBC Website 2011).

Despite relative calm in media portrayal, the conflict is ongoing and far from being resolved. To this day, lives are lost by UN peacekeepers, civilians, army and militias, accounting for hundreds and even thousands of deaths every year. The country today is struck by grieving poverty, displaced people and famine. The climatically and socially restraining influences turn Darfur into one of the most inhospitable places on this planet.

2.2   Introduction to UNAMID

The intervention of international organizations was slow and at first under the auspices of the African Union (AU). The NIF regime in Khartoum was delaying intervening efforts successfully and was at its face conciliatory. It knew how to use diplomacy from its sheer endless negotiations in southern Sudan, which was still the primary international focus. At the other end, international coordination lacked resources and determination. Additionally, diplomacy was caught up in bureaucracy and enduring reconciliation. In 2004, two peace negotiations were initiated. The first was under the lead of the Chadian government, ending with a disappointing 45 days' truce. The AU led the second peace conference and drafted a poor paper with little tangible results. Even worse, both agreements were broken "before the ink was dry" (Daly 2007; p. 295).

At the time, the UN invoked its 'Brahimi principle', which is a directive that regional organizations should take care of conflicts in their own backyard. The principle is named after Lakhard Brahimi who coined the directive in the year 2000 (Flint et al. 2005; p. 117). However, the African Union failed and was hopelessly under-equipped to handle the scale of the Darfur conflict. The UN first discussed the issue formally in May 2004. In January 2006, grossly lacking the funds to operate in the harsh environments of Darfur, the AU publicly called for the UN to take over the lead in the prevention of further violence which it finally did in 2007 (Daly 2007; p. 301). In the meantime, the Sudanese government and the Sudan Liberation Movement (SLM), the political wing of the SLA, signed the Darfur Peace Agreement on 5th May 2006. The peace agreement was an extensive accord covering security and ceasefire arrangements, rehabilitation and political development.

Security and ceasefire called for the halt of violence by both sides, the rebel groups and NIF/Janjaweed. It also explicitly demanded the disarmament of the Janjaweed. Rehabilitation summoned the protection of civilians and the establishment of demilitarised zones around the IDP camps. Political developments will have far-reaching consequences not only for Darfur but the country as a whole. It includes more autonomy, though the rebels at no stage demanded the secession of Darfur from Sudan, and a better say in

government decisions through increased participation in key positions (Sudan Tribune Website 2011).

In theory, the DPA is a huge success for the rebel groups, for the government concedes many favouring issues of peace, security, human rights and self-determination. Nevertheless, only the Sudan Liberation Movement signed the agreement. The SLA and JEM refused to sign. On the other side, the national government's huge disparities of wilful declarations and actual implementation have almost always been irreconcilable. These prerequisites will dare the success of the agreement.

Today, the United Nations / African Union hybrid mission in Darfur (UNAMID) is, matter-of-factly like *all* peacekeeping operations of the UN, institutionalised by the Security Council. The legitimising resolution 1769 was drafted in the year 2007 under Chapter VII of the United Nations founding charter (UN Security Council 2007: Resolution 1769). Chapter VII of the United Nations Charter deals with crisis response to "threats to peace, breaches of the peace and acts of aggression" (UN Charter 1945). This chapter ought to be seen as the most rigorous of the chapters that deal with resolving disputes, i.e. Chapter VI-VIII, in that it explicitly allows the use of armed force in an otherwise constructed paradigm based on consensus and negotiation as the main means of conflict resolution. However, should these measures and other non-military disciplinary action such as economic sanctions fail to succumb an aggressor, the UN may take "action by air, sea, or land forces as may be necessary to maintain or restore international peace and security" (Chapter VII; Article 42). To maintain and restore international peace and security is the UN's main assignment and founding principle.

Peacekeeping, although not explicitly provided for in the establishing UN Charter of 26th June 1945, has evolved to be the main tool in ending violent conflicts (Capstone Doctrine 2008; p. 24). The Capstone Doctrine outlines three principles which peacekeeping operations must abide by. Firstly, a ceasefire agreement must be *in existence*. Secondly, UN peacekeeping operations are to adhere to *impartiality*. Without the consent of the involved parties, a peacekeeping operation risks to be drawn into the conflict as another aggressor. Thirdly, and in contrast to peacemaking and peace-enforcing missions, peacekeeping

operations do not permit military force as such but is only validated for *self-defence* and *defence of the mandate* (Capstone Doctrine 2008; p. 31-22).

In brief, the purpose of resolution 1769, which is providing the legal framework for UNAMID, is to support the Darfur Peace Agreement, protect civilians and ensure a restoration of law and order that nurtures economic reconstruction and development (UNAMID Website 2010). These points only briefly summarize the key objectives of UNAMID's mandate. The entire mandate can be accessed in *Appendix 1, p. 86*. The first objective, to support the Darfur Peace Agreement, indicates that peacekeeping is a term used for missions whereby the confrontational parties have already put down their weapons, negotiated a truce, armistice or similar agreement, however volatile that arrangement may be. This puts peacekeeping in one of the more advanced stages in the political process and assumes a *post-conflict* approach. This clearly distinguishes peacekeeping from other, much more rarely implemented concepts such as peacemaking and peace enforcing. A guidance of the distinction between these various terms offers the following illustration. The overlapping ellipsoids account for grey areas that have no clear-cut definitions in place.

Figure 2   UN means of maintaining international peace and security
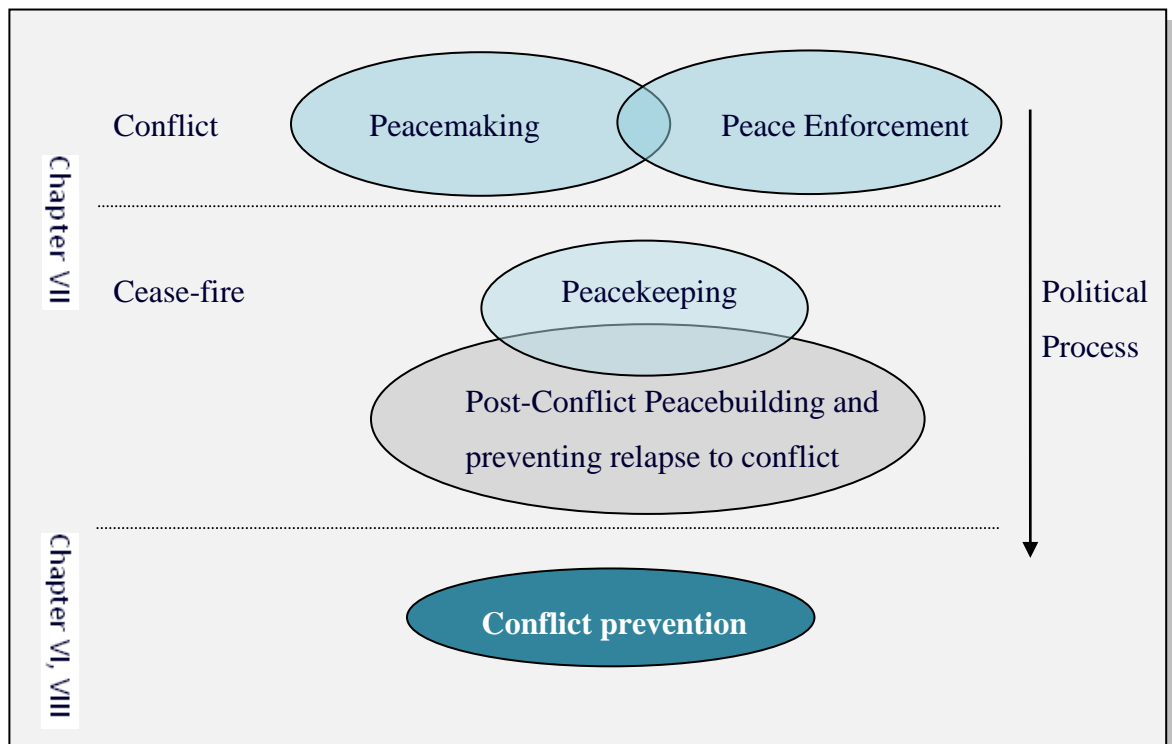
A pivotal difference as outlined in *Figure 2* between the conflict and ceasefire stage is that the former uses coercive action at an international level, which is normally prohibited under Article 2(4) of the UN Charter whereas the latter uses military force, if necessary, with the consent of the host government (Capstone Doctrine 2008; p. 19). This also applies to the Darfur peacekeeping mission, which at least theoretically has the consent and protective assurances of the government of Sudan. This consent also obliges the host government to participate in the political process of working towards a stable and lasting peace.

These aspects often portray an illusionist picture of reality, however, and as witnessed in UNAMID, missions often lack a commitment of the parties involved and consent can soon turn into intimidation resulting in a *de facto* withdrawal of consent. Furthermore, in absence of a stable rule of law and violence against civilians and between aggressors, a ceasefire agreement is often nothing more than a futile document. Violent clashes in Darfur occur on a daily basis and to speak of a ceasefire phase or even peace agreement is a deceiving assumption.

The role of peacekeeping in conflict resolution ought to be seen as one of the first stages in an often very long process in which lasting stabilization is one of the key endeavours. This is why peacekeeping operations are military in character. In achieving a perpetual peace, they preoccupy a time span in the beginning and are shorter than the other cycles, though these operations can last for decades (Capstone Doctrine 2008; p. 21). To achieve an enduring peace deems more phases necessary, involving peace consolidation and economic recovery. Furthermore, a successful cycle of these phases by no means guarantees peace. Hatred and prejudice are often more dominant factors in reconciliation, thereby obstructing even serious efforts. In many conflicts they simmer for decades under the lid of all good intensions, effervescing in arbitrary and unpredictable patterns.

Darfur shows many criteria of the volatile stabilization phase that coincide with the incapacity of the State to secure the protection of its population and maintain public order. A large number of IDPs, ongoing violence, human rights abuses and a gross lack of basic infrastructure all support this view. To overcome these deficiencies and to support the

mission's mandate, UNAMID is today's largest of the currently 16 peacekeeping missions[3], involving the deployment of vast resources. The number of troops and police is at 20,000, civilian support staff amount to another 6,000. The mission's budget for the fiscal year 2008-2009 was $1.7 billion (UNAMID Website 2011). Nevertheless, the mission struggles with huge problems concerning the realisation of its mandate.

The obstacles faced are an interfering and obstructing government, huge stress on the resources due to a prohibitive environment in hot and arid climate and logistical problems because of its remote location. There is also concern about the inefficient use of resources within its own constitutional framework. Though the budget is huge, not all money is put to its best use and the lack of market-driven mechanisms hinders a successful operation. The inherent dangers are an apparent threat, looming in from within and outside the system.

These obstacles reduce the mission's effectiveness to a large degree, absorbing much of its resources before they are even set up. In short, the road of the mission ahead is a precarious one, far from any achievements as outlined in the mandate and its success or failure is yet to be determined.

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[3] As of 2010, the 16 peacekeeping missions are run in the Middle East (UNTSO), India/Pakistan (UNMOGIP), Cyprus (UNFICYP), Syria (UNDOF), Lebanon (UNIFIL), Western Sahara (MINURSO), Kosovo (UNMIK), Democratic Republic of Congo (MONUC), Afghanistan (UNAMA), Liberia (UNMIL), Côte d´Ivoire (UNOCI=, Haiti (MINUSTAH), Sudan (UNMIS), Timor-Leste (UNMIT), Darfur (Sudan) (UNAMID), Central African Republic/Chad (MINURCAT)

2.3   GIS in peacekeeping operations

"The business of the United Nations is inseparable from geography" (UNCS 2009; p. 1-1). Geographic information services are integral and substantive part of peacekeeping operations. If the role of GIS in peacekeeping operations is dismantled to its principal objectives, it becomes evident that geographical information is vital for security and economic reasons. More precisely, GIS plays a pivotal role in the following:

- Improve security
- Reduce informational deficiencies
- Reduction or avoidance of operational cost
- Improve efficiency of mission operations

The most important of these considerations is beyond doubt security. GIS is a life-saving technology. Peacekeepers have a gross disadvantage of operating not only in harsh environments but of also lacking knowledge about their surroundings. This is a key deficit as compared to the belligerents that are almost always very familiar with their territory and retreat lines. Geographical information and its careful analyses can narrow this gap. The American Headquarters of the Army have an even more extreme view in that they perceive "the engineer's GI&S technology [is] the cornerstone for information dominance that is critical for a smaller, agile, and more lethal army" (Dep. of the Army 2000; p. vi). This statement lacks an important aspect with regards to its own troops. A smaller and agile army also reduces its own fatalities.

In the United Nations Department of Peacekeeping Operations (DPKO), cartography and GIS is one of the many departments that constitute the Integrated Support Services (ISS). GIS, first and foremost is an intelligence component, supporting many aspects of peacekeeping operations through all cycles from planning to liquidation. Understanding the environment in which to operate is a vital prerequisite to conduct successful operations. This becomes even more important in an early stage of deployment. An early start of operation is perceived as one of the key success factors for establishing a sustainable peace accord (UN GIS Operational Manual 2003; p. 1-2). Vice versa, the initial stage of

deployment is often witnessed by a substantial lack of sufficient information with regards to geography. Geographical reference is needed for many military, strategic and operational matters such as rebel, force or IDP movement, security information or logistics.

Peacekeeping operations are a highly dynamic undertaking. The infrastructure has to be rapidly set up and operational. It also often has to shift focus to new events. These changes require immediate attention to move, halt, change or even dissolve operations. The events are mostly triggered by outside circumstances and are out of control to the management of peacekeeping operations.

In the course of time, peacekeeping operations have become more complex. Originally, they were set up in well-defined inter-state conflicts with known perpetrators and the actors were governments. After the post cold war period, however, the bipolar world as we knew it collapsed and with it, it seems a lid has been taken off igniting a broad number of conflicts that have been becoming increasingly asymmetrical. Whereas there is an ongoing debate as to whether the Cold War has been a more secure place to live in or not, it is beyond question that since the early 1990s, the number of internal armed conflicts at any given time has increased. Not surprisingly, there are more than 124.000 personnel from more than 115 countries serving in peacekeeping operations today. In the fiscal year 1.7.2009 - 30.6.2010 the comprehensive budget of peacekeeping was approximately $7.9 billion (UN Website; Peacekeeping facts). Asymmetry has also changed the nature of these conflicts. Actors have become vague, boundaries are less and less adhered to, power has shifted and is often very inequitably distributed. Civil wars, terrorism, insurgency, kidnapping and ambushes are all phenomena that suggest an increasingly fuzzy and less visible enemy.

This complex nature has important implications for GIS. The complexity has to be bolstered by providing fast, accurate and reliable geoinformation, demanding ever more efficient means of data processing. Such demands introduce comparatively recent concepts of spatial interoperability and the need to transmit geoinformation between constituents with standardized methods and beyond the constraints of locked applications or operating systems. Only interoperable standards will fully embrace the requirements to provide the

information to military, other UN agencies or non-governmental organizations in a timely manner.

Interoperability is a fairly recent development that has only currently swept over from other information technologies and often is not much in line with classical GIS practices that have traditionally occupied niche systems and markets in the past. Not surprisingly, interoperability has only begun to be leveraged. The true capabilities of this concept and its advantages are yet to be fully deployed. Notwithstanding, a Common Framework of Geographic Information System Architecture (CFGISA), as called for by the UN headquarters, is probably nowhere more beneficial than in the settings of dynamic peacekeeping operations. Standardization can reap enormous benefits in setting up operations and exchanging information between its various stakeholders inside and outside the UN system.

The professional network "United Nations Geographical Information Working Group" (UNGIWG) has realised this need and perceives interoperable standards as one of the main instruments to leverage these advantages. Three out of the five network's mission statements directly deal with an efficient geographical information exchange:

- Improve the efficient use of geographic information for better decision-making
- Promote standards and norms for maps and other geospatial information
- Build mechanisms for sharing, maintaining and assuring the quality of geographic information

Within UNGIWG there is an "interoperable services" task group dealing with "improved access and use of spatial data to enhance data sharing (…) through international standards and specifications (UNGIWG Website 2011). These are translated into the ISO/TC211 standard number 19115 (Geographic Information/Geomatics). The Open Geospatial Consortium (OGC) works in close cooperation with the ISO/TC211 working group. OGC standards like WMS, GML and Simple Features Access specifications today are also ISO standards. Consequently, the distributed proposal of the SIRS application is fully in line

with UNGIWGs interoperability ambitions and conforms to the facilitation of geoinformation sharing.

In terms of operational matters for peacekeeping missions, interoperability ensures that newly set up operations need not establish new rules and practices but can immediately draw upon established guidelines. Secondly, no information is lost due to inaccuracies of methodologies (i.e. metadata of geoinformation) and the information cannot only be readily integrated with other existing information but also easily disseminated to other parties. Thirdly, data accessibility is facilitated and data management can occur in a transparent manner. These factors in turn avoid redundant and faulty data. For these reasons, turning a blind eye to such innovations would be nothing less than irrational.

Before moving on to the next thoughts, a brief summary of the benefits of interoperability and standardization methodologies is provided:

- Increased security of operations
- Reduced cost of operations
- Ease and speed (up to real time) of exchanging information, regardless of applications, operating systems and actors involved
- Foundation of established guidelines for future use
- Seamless integration with existing geoinformation
- Central and transparent data management
- Avoidance of redundant and erroneous data

2.3.1 Availability of geographical information in UNAMID

The initial stage of missions has to cope with a deficit of appropriate data to support its various demands. Readily available are only small-scale maps, i.e. larger than 1:50.000 as the likes based on the Digital Chart of the World (DCW), LandSat-7, ADRG, CADRG, VMAP-0, DTET Level-0 and commercially available satellite imagery. Here, SPOT©, GeoEye©, IKONOS©, Quickbird© cater for the needs of up to a resolution of 60cm/pixel

(UN GIS Operational Manual 2003; p. 10). A visual representation of available raster images is also provided in *Figure 3, p. 25.*

In many cases this does not satisfy decision-makers that need either more detailed or specialized maps with specific thematic content. For this reason there is a high demand of locally collected geoinformation that reflects the relevant aspects of the mission. These areas, for example, include broken bridges, load capacity and condition of the bridges, unpaved/damaged road conditions, available airport/heliport capacity, sea port condition, team (troop) sites with detail conditions, transit camps with detail information, available facilities, flooded area, environmental hazardous area, check points, by pass route, status of troops/rebels/team sites, incidents, etc. (UN GIS Operational Manual 2003; p. 10). The technical implementation of this thesis will deal with the provision of such thematic data in a way that renders the dissemination of geographical information easy and fast to view, interoperable and quick to update. More specifically, the application will propose a system to increase security insufficiencies. Increased security is causal to the quality of (geo)information. Peacekeeping missions can increase the quality by embracing new forms of data distribution and data content.

2.3.2 Enhancing the availability of geographical information

If the presage of more information equalling more security holds true, there is need to tap new sources of information. *Figure 3* evaluates the difference between existing UNAMID versus freely available image maps on the Internet in which providers such as Google© take the lead in the quality of geoinformation. Maps of such likes share many characteristics of a public good. A public good, by definition, is defined as nonrival and non-excludable (Kaul et al. 1999, p. 3). Non-rival implies that the consumption of one person does not decrease the value of the good for another person. Non-excludable indicates that no person can be excluded from enjoying that good. According to these definitions, information fulfils both criteria. As opposed to limited resources, information does not deplete or lose value and can be consumed by any interested person regardless of position or wealth. In terms of peacekeeping, the inclusion of public information decreases the reliance on costly procurement of satellite imagery and can be accessed free of charge.

To contrast the quality differences, *Figure 3* exemplifies the UNAMID and Google©
Hybrid satellite image coverage. Despite extensive expenditure for satellite imagery in
Darfur, which amounts to more than US$ 400,000 for the fiscal year 1.7.2010 - 30.6.2011,
UNAMID loses every comparison with Google©. Coverage of Google© is more up-to-
date, covers more high resolution areas and provides a faster and technologically more
advanced service, readily available to be used in open source applications. Through
additional public WMS, this gap is even further widened.

Figure 3   UNAMID – Google Hybrid comparison (Darfur and headquarters)
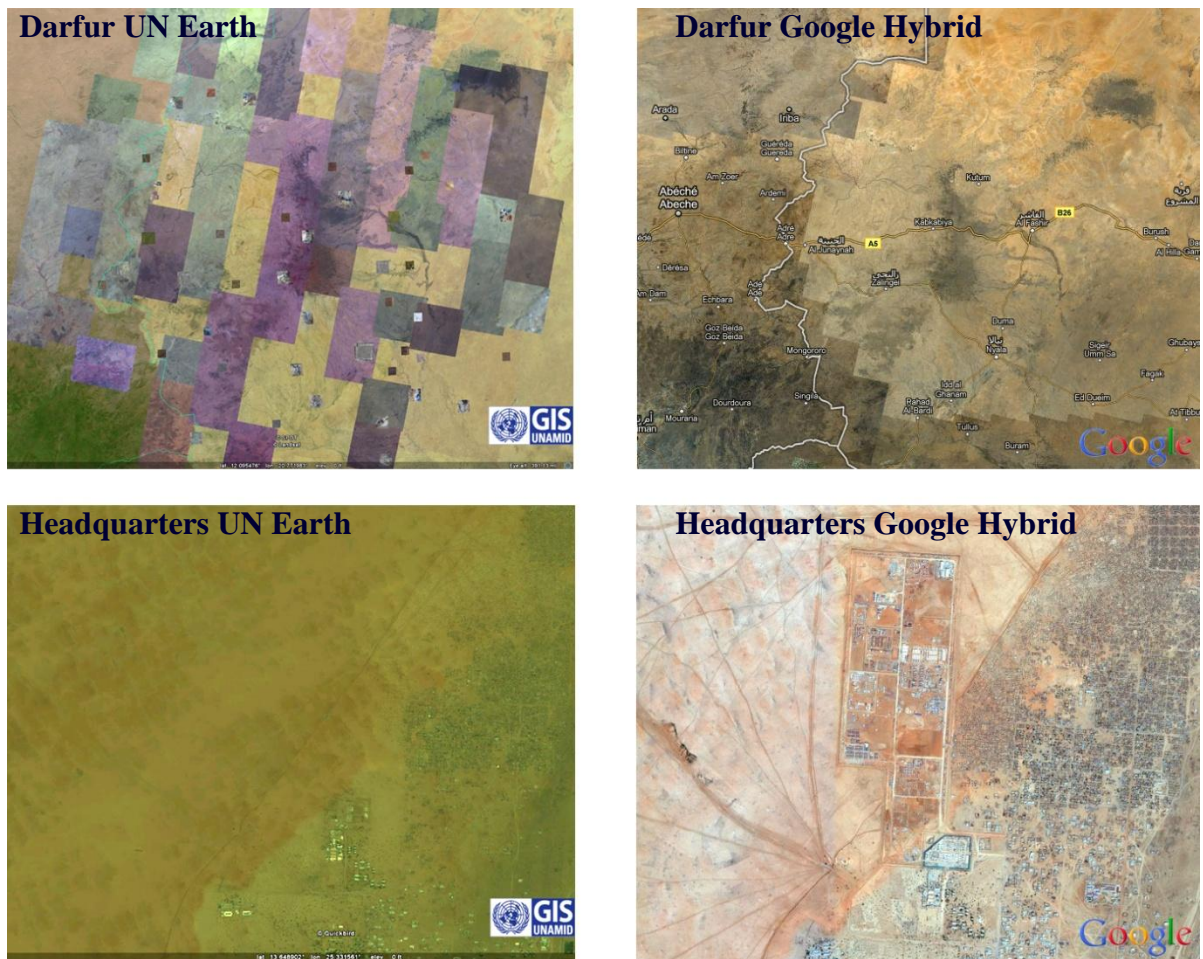
The illustration provides two comparisons. Firstly, the two top images compare (most of)
the region of Darfur. On the left, UNAMID provides only high quality images for UN
locations. These can be witnessed in the tiny rectangles that are scattered throughout the
image. High resolution refers to Quickbird© satellite images at 60cm/pixel. Furthermore,
there are extensive SPOT© satellite strips covering large areas of Darfur. These strips have

a resolution of 5m/pixel (as evidenced in the dominant purple bias of data). Lastly, there are also LANDSAT© imageries with a low resolution of 15m/pixel. The comparison with Google© Hybrid on the right shows a *complete* coverage of Quickbird© 60cm data.

The second example, the two bottom pictures, shows the same high resolution data for UNAMID headquarters. The supercamp infrastructure is completely missing in UNAMID coverage, dating from the year 2007. Comparatively, Google's© Hybrid Layer incorporates 2010 Quickbird© images. It is immediately evident that Google© Hybrid is by far more up-to-date and provides wider high-resolution coverage. For these reasons, an integration of the Google© base layer is a convincing argument.

A probably better approach is to think of these different entities as complementary and reciprocal and not as competing ones. And this is exactly where the main strengths of such an application rest; in the use of existing base maps (Google© Hybrid, Yahoo© Maps, etc.) and to configure the final application in such a way that uses own data to overlay these base maps. The combination of such data can yield ample results that bring together different sources each with its own strengths, thereby also limiting individual drawbacks. These postulations provide a stable foundation for inclusion in the security incidents application.

2.3.3   Security Incident Reporting System (SIRS)

One of the biggest advantages, and hence adopted for this paper, is to develop an application that can visualize the dispersion and occurrences of security incidents. Incidents are referred to as either criminal activities that are targeted at UN staff or premises such as carjacking, assault, kidnapping, robbery and murder or as impediments carried out by authorities such as denial of access or arrest.

These incidents can deliver persuasive insights about where they occur and be further used to develop appropriate mechanisms to alleviate their number. Displayed on a map, analyses, policies and endorsements to counteract such tendencies will fall on more fruitful grounds. The geographic display can hugely benefit operational issues for security and deployment sections. The visualization will speed up management decisions, especially the

ones that need a quick resolution. This is where the application will achieve its strongest advantages.

Nevertheless, once the application is embedded and widely adopted by its users, it can also be used for further and strategic analyses. A wide array of outputs may help to analyse trends and generate a body of comprehensive data for higher level analyses. Through additional layers and adjustments of geoinformation, it can also be used for other security measures like staff residence locations, evacuation plans, rebel movements, etc. For the scope of this paper it will solely focus on delivering an intuitive and easy-to-use interface for relevant sections to maintain, edit and visualize security incidents occurring within the mission.

Any implementation of a distributed geographic information service should largely focus on the user's acceptance. The system design should thus always bear in mind that it is used and edited by people that most likely do not have a background in GIS. The successful adoption of a service, for this reason, should be an intuitive, non-complicated and user-friendly application. This also explicitly implies that such a service needs to do most of the work in the background. Only the tip of the technological iceberg should be visible and manageable by the user. This is for good reason. Chapter "*2.3 GIS in peacekeeping operations*" outlined that GI services need to be available to better control risky or unknown situations. On one hand, solutions have to be readily available and in case of an emergency easy to locate and retrieve. On the other hand gathered information needs to be painlessly written back to the database to allow for quick updating. Security linearly improves with speed and ease of the information flow.

The theoretical paradigm above has outlined that the emergence of information will facilitate and enhance security for UN staff which tends to work in unpredictable environments. To this end, mapping will deliver its part to take out some degree of this unpredictability.

In order to practically implement the application, the introductory chapter has outlined the five requirements that need to be fulfilled in the application. Though these five simple

points seem straightforward and reasonable to apply, it has at the same time narrowed the choice of software for its infrastructure significantly. The reasons as to why this is the case are to follow in the next chapters. Preceding chapters embedded the technological application of the incident reporting system in its theoretical foundation. The second part of this paper is concerned with the implementation of the actual application; *id est* to visualise and administer the security incidents database.

3   Technological implementation of the security incidents reporting system

The introduction outlined in its requirements the need to manipulate geoinformation from various locations throughout the mission. A fully developed UNAMID intranet highly suggests an application that builds upon this infrastructure. The intranet has two immense advantages; increased security and the benefits that are reaped through distributed computing.

A clarification between the term internet and intranet shall serve as a starting point to identify the difference between the two expressions. Firstly, they share a lot of resemblances and in many ways can even be used interchangeably, especially in technical terms. For, both describe a network between computers using the internet protocols TCP/IP. The IP address hereby is the main mean of sending datagrams from a host to a destination computer. The Transmission Control Protocol (TCP) ensures that the datagrams are delivered reliably to the destination computer. Reliably in this context means that TCP assures that the connection between client and server is properly commenced and finished, that the datagrams are transferred in the right order and that lost or damaged datagrams are initiated for repeated download (Abts 2010; p. 117).

The main difference of an intranet, and this also applies to the UNAMID Intranet, is that they are private networks restricting access by a proxy server to only allow permitted users to access the network (Wikipedia 2010; Intranet, IP, TCP, Private Network). Thus, an intranet can be seen as an internet with additional security measures to secure its resources by filtering the information through IP addresses and/or protocols. This has tremendous advantages for SIRS because security considerations can be fully capitalised and there is initially no pressing need to implement additional security measures. For this reason, it only takes a subsidiary role in the implementation of the SIRS infrastructure. Nevertheless, to further steer user control, Chapter "*3.7 Security considerations*" implements additional server-side user authentication.

3.1   Distributed computing

The terms distributed computing, interoperability, web services, and service-oriented architecture all operate in highly coinciding environments. It is not part of this paper to delimit and define the often slight differences but to stress that the application applies many of these concepts in its implementation. The purpose of all these schools of thought is to enable a seamless sharing of resources among and between organisations in a platform-neutral and language-neutral manner (Chappell et. al 2002; p. 6). This can only be achieved through standardisation. Today the most common standard of information sharing is through the HTTP protocol and XML data representation. The geographical markup language (GML), as a dialect of XML, neatly fits into this description. Distributed computing decouples the business logic from its tight proprietary infrastructure, i.e. software and platform-*specific*, and allows a distribution to any connected resource on the intranet/internet where it is received and used for proprietary use again. Similar to humane synapses, data transmission needs to implement junctions where information is received and handed over to the next application. Interoperability never is a 100% vertical integration as the inclusion of proprietary systems already forestalls.

Such digital synapses are called interfaces and are implemented through Application Programming Interfaces (API). SIRS needs to implement APIs for the connection from MS SQL Server© to ArcSDE© to GeoServer to OpenLayers and vice versa. APIs describe a set of interoperable rules to get access to resources and retrieve the data from these sources. APIs ensure interoperability regardless of the source's software and hardware implementations through the defined rules as incarnated by the HTTP protocols and XML (GML) data transmission.

The concept of integrating data or functionality in web development from various sources is also referred to as *mashups*. The purpose of a mashup is to enrich the value of information and extend its content by combining various sources of data (Wikipedia 2011; Mashup). APIs are responsible to get these different sources together. SIRS is a first-rate example of a mashup with API specifications using interoperable information exchange standards.

These considerations illustrate why interoperability is a software implementation between computers. The most dominant interoperable architectures are peer-to-peer and client-server. Both frameworks have in common a distributed approach towards information sharing and are a progression from monolithic structures, i.e. all applications are run on one computer, which were by and large the only option before the advent of the World Wide Web. The advantages of the client-server architecture in a distributed environment, as opposed to peer-to-peer systems, are its focus on central storage and its better security and maintenance capabilities. These are important advantages with regards to the peace mission's settings and the reason for its adoption.

With regards to SIRS, interoperability implies the possibility to disintegrate the core components of the application. These are presentation, processing and data storage, allowing the components to be effortlessly separated through the standardized protocols (Abts 2010; p. 6). The disintegration improves scalability of the system and allows the components to be developed independently.

A presentation of information may be retrieved in any intranet-connected computer within the mission whereas data processing and data storage are accomplished autonomously on different computers or servers. This division is hidden from the user who accesses the information through only one component, namely the web browser, reflecting the need to provide an intuitive interface for the end user.

Abts (2010; p. 7-8) cites various advantages and disadvantages for distributed computing architectures. The benefits of recording incidents from numerous locations by far outweigh the disadvantages, which are further mitigated by countermeasures. Advantages of a distributed approach include the following:

- **Realistic application**
  The distribution supports the lean organization of the mission. Efforts are generated where they are needed. Data can be accessed and manipulated in different teamsites and mission sectors and from users that know the details most comprehensively.

Distribution improves accessibility. As argued above, accessibility is one of the key factors in enhancing security.

- **Efficient use of resources**

  Information can be retrieved without extensive computer requirements in remote locations. All that is necessary is a basic personal computer with intranet access. Reducing hardware requirements reduces operational costs and again improves accessibility of geoinformation.

- **Improved distribution of workload**

  The information sharing supports a better distribution of workloads. The option to work from many computers facilitates a division of work. The speed to obtain geoinformation is improved.

- **Better scalability**

  Since many computers can work on the data simultaneously, there is room for growth. An expanding mission can easily accommodate more users in more locations.

- **Improved fault tolerance**

  The failure of one computer does not break down the application. Especially if the servers and databases have a backup scheme in place, the application can reliably continue to operate, should one or several computers fail.

On the other hand, distributed computing has pitfalls with regards to the following factors:

- **Higher complexity**

  Distributed computing often handles various operating systems, programming languages, data formats and communication protocols. This heterogeneity exposes the application to more vulnerability.

- **Increased expertise in development and administration**

  The ability to accommodate competing infrastructures demands higher knowledge of both developers and administrators. As opposed to off-the-shelf infrastructures, such as ESRI ArcGIS Server©, it involves more careful changes to the application and increased time and knowledge to ensure stability, security and performance of the application.

- **Higher security risks**

  Any distribution and transmission of data through HTTP protocols increases the risk of data phishing and deliberate and intrusive system intervention and corruption.

Most disadvantages can be reduced through improved security measures and the development of a stable application that is built through extensive testing and debugging. Secondly, the advantages of a distributed platform cannot be ignored and put forward a strong case for such an approach.

3.2   Server-client infrastructure

The above-mentioned case of facile and speedy information exchange strongly suggests a thick server – thin client infrastructure. Such a model proposes a client application that only has the most basic features available and thus heavily depends on the server to perform the essential operations. The principle is that the server hosts all the information, which is per request downloaded to the client and run within a browser.

The client only needs a basic computer or mobile device as well as an Intranet connection. A GIS software, database or extensive computational resources need not be present on the client-side. These tasks are all accomplished by the server. However, the assumption that a thin client is not a significant component is at best misleading and at worst erroneous. The client, no matter how thin or slim it is, is the pivotal link between the server and the user. As such it has to do the following:

1. Handle the user interface.
2. Translate the user's request into the desired protocol.
3. Send the request to the server.
4. Wait for the server's response.
5. Translate the response into "human-readable" results.
6. Present the results to the user (Infomotions Website 2010).

This explains why the client needs to translate and exchange all information between the server and the user in a transparent and straightforward manner. The gateway between the user and client is referred to as the Human-Machine Interface (HMI). Whereas the importance of this concept is beyond doubt vast, involving human perception and semantics of symbols, maps and, as a matter of fact, all other information contained within the client, the scope of this study will not further delve into this topic. Here, it is suffice to acknowledge that any such interface needs to consider its intuitive implications for the user as well as the efficient communication with the server.

When the client communicates with the server, the latter has to process the client's request. The client's request has to be interpreted, processed and returned. It is also important to

note here that the request can be as diverse as getting feature information, changing the map content and manipulate data such as editing, deleting and updating geographical information. This diversity vastly narrows the eligible software components.

3.3   Technological components of the application

The backbone of all geographic data for UNAMID, particularly its vector data, is the ESRI ArcSDE© database technology. As a middleware it connects ArcGIS© with a relational database management system (RDBMS), which, for UNAMID, is Microsoft SQL Server©. The application should draw data directly from these sources to avoid redundancy by storing it multiple times. It would be too error-prone and lack up-to-datedness to transfer data from one system to the other, though this has been done for development and performance reasons using a local PostGIS clone of the incidence database. This ability ensured continuous improvements of the system outside the UN Intranet or mission area. PostGIS is one of many open source developments that have come to the geoinformational forefront in recent years. Indeed, many of the open source projects have become so versatile and powerful that they are on a par with commercial systems. Even more so, looking at the OGC standards, they have become *de facto* standards for sharing geographical information on the internet. For these reasons, the technological implementation will heavily depend on these technologies.

By doing so, it will implement the OGC standards for data transmission, GeoServer as the geospatial server, OpenLayers to provide dynamic and user-defined maps for the client and GeoExt for a visually appealing website. The following chapters will take a closer look at these elements, starting with the OGC standards for sharing geoinformation on the internet.

3.4 OGC standards

The OpenGIS© community has lowered the cost barrier to use geographical information science for webmapping applications. Webmapping has opened up geoinformatics for skilled IT and GIS specialists to adopt common, though modified, IT standards and has increased the number and dispersion of online mapping. The open source nature has the additional benefit that it steps out of proprietary and locked systems as provided for by, for instance, ESRI©. The comparable webmapping platform ArcGIS Server© has many advantages in that it can deliver very fast and sound solutions. ESRI© has also seen the need to open up its applications to trends in the market and its users may now incorporate various open source technologies. Examples are ArcGIS© Server's REST, SOAP and JavaScript APIs or its Web Developer Framework. Yet, it remains a costly, proprietary and locked application from the point of view of developers. Such an insulated model can in many respects not reach full capability of current webmapping solutions. Today, however, open source developments are increasingly noteworthy for delivering a huge body of GIS applications. Examples include OsGeo, an extensive open source community that provides many standardized and widely adopted tools for GIS. GDAL is a massive library for geoprocessing; Proj4 offers full access to the European Petroleum Survey Group (EPSG) codes, defining over 4000 projections; software applications deliver advanced geoprocessing capabilities from proprietary, e.g. QGIS, GrassGIS to embedded, e.g. libtiff or Shapelib. All these applications are fully able to be tapped from scripting languages such as Python or JavaScript, which are very powerful and versatile languages for applied geoinformatics.

There are more compelling reasons to use an open standard on the client side. For one, today's clients can easily communicate with proprietary databases such as ArcSDE©. Indeed, they offer mature support for most commercial database applications like Oracle©, DB2© and open source databases such as PostGIS. The architecture is hence leaving the ESRI© community and uses only its database technology to plug in, using GeoServer's ArcSDE© API.

Geoserver's ArcSDE© plug-in needs to be downloaded in fragments from a number of sources including ESRI©. GeoServer can fully tap the ESRI© database technology after configuring the database parameters correctly.[4] After moving the libraries into the designated folders and configuring the parameters, GeoServer can fully connect to ArcSDE© instances. This is one of the pivotal reasons for using GeoServer with regards to the development of an incidence reporting system.

Another persuasive reason is, as opposed to other webmapping servers such as the UMN Map Server, GeoServer's ability to edit geodata. These two factors ensure a webmapping application that combines the best of both worlds; a strong and existing database technology that is used for an open, easily distributable and programmable web interface for visualisation and database management.

3.5   GeoServer

The GeoServer application is the Open Geospatial Consortium's reference implementation for its WMS, WFS and WCS standards. It is a Java written geospatial server allowing users to edit and disseminate geospatial data (GeoServer Homepage 2011). As Apache is an open source HTTP server for publishing webpages, GeoServer enhances web applications by allowing the publication of geospatial data. GeoServer has a pre-installed OpenLayers library to display dynamic maps in web browsers. The main difference to common maps published on the Internet is that OpenLayers serves dynamic maps with optional layer displays, i.e. they can be turned on and off, panning and zooming and a variety of other powerful GIS tools. Another strong case for the deployment of GeoServer, as briefly mentioned above, is that it is able to use the WFS-Transactional protocol (WFS-T) and thus GeoServer supports INSERT, UPDATE and DELETE operations. In short, geodata can be edited in the GeoServer/OpenLayers environment.

---

[4] The installation of the ArcSDE plug in requires apart from the geoserver-2.0.2-arcsde-plugin.zip main extension from http://sourceforge.net/projects/geoserver/files/GeoServer%20Extensions/2.0.2/geoserver-2.0.2-arcsde-plugin.zip various other Java libraries like jsde_sdk.jar and jpe_sdk.jar from http://support.esri.com/index.cfm?fa=downloads.patchesServicePacks.listPatches&PID=66 and icu4j_3_2.jar from ftp://ftp.software.ibm.com/software/globalization/icu/icu4j/3.2/ (only for ArcSDE 9.2 and higher)

Figure 4 provides an advanced introduction about the various modules of the OpenGIS©
architecture for webmapping purposes. The green lines provide guidance as to what
precisely is implemented in SIRS.

Figure 4   OpenGIS© architecture

Source: http://en.wikipedia.org/wiki/OpenGIS
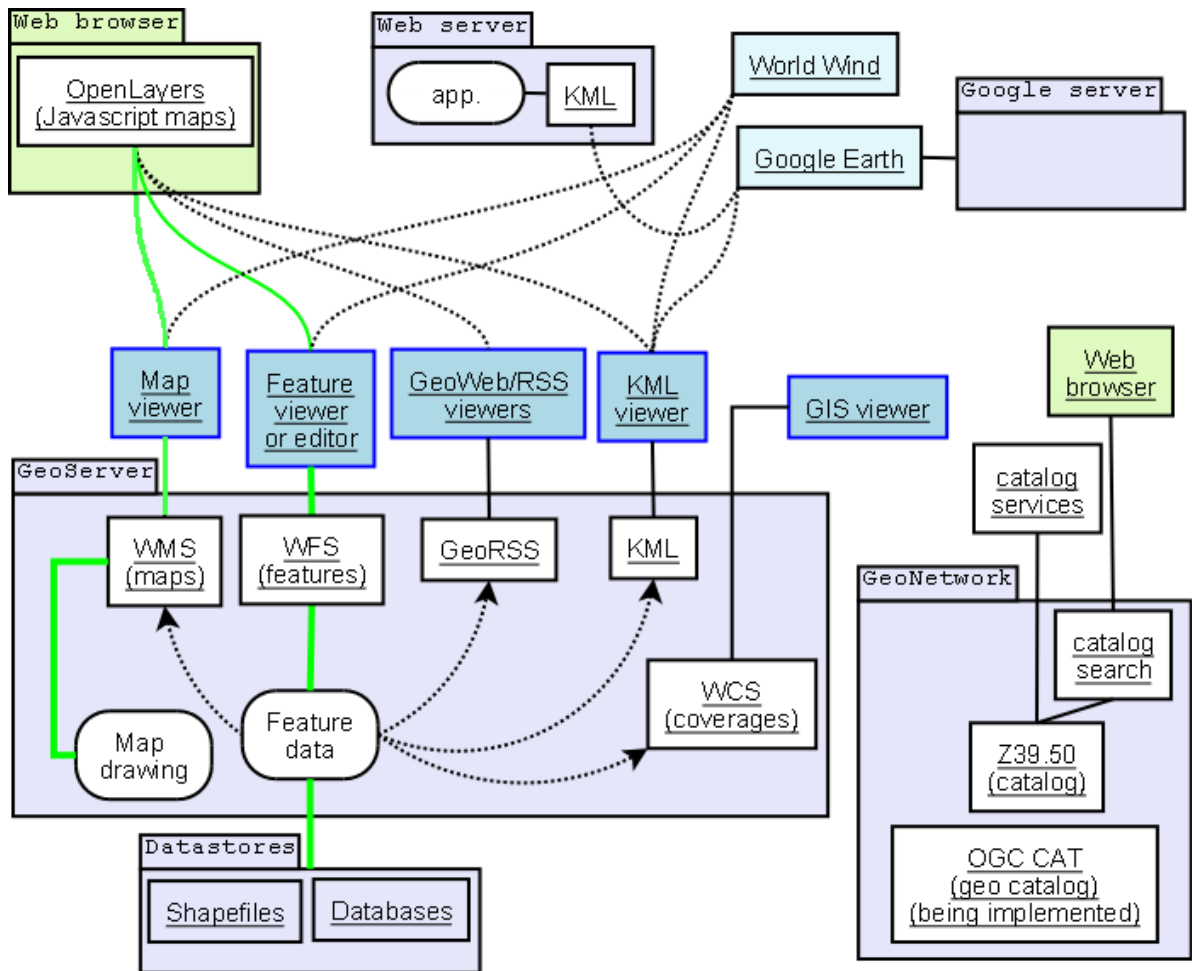
The advantage of open source GIS undoubtedly lies in its smooth alignment with open
standards as defined by the Open Geospatial Consortium (OGC). The main standards
defined by OGC and of interest to webmapping developers are the Web Feature Services
(WFS), Web Map Services (WMS), Web Coverage Services (WCS), Styled Layer
Descriptors (SLD) and Catalogue Services for the Web (CSW).

The rationale behind using these implementations is that drawing upon existing services, an abundance of freely available geoinformation can be retrieved from other sources. This enhances the value of the application by being far more accurate, comprehensive and versatile than the UNAMID GIS section could ever achieve by itself. This paradigm was further scrutinised in "*2.3.2 Enhancing the availability of geographical information*".

3.6 Developing the webmapping application

The process of preparing geographic layers in GeoServer for publication and use in a website involves the following steps:

- Creating a **workspace** to which the instances are referred to. This is done through the GeoServer Web Interface and for this application is the reference URL:

  http://localhost:8080/geoserver

- Creating a **store** that contains the connection parameters to the data to be used.

  The key parameters for the database connection to gain access to the relevant layers are as follows:

	PostGIS	**ArcSDE**
Workspace:	MasterThesis	MasterThesis
Data Source Name:	PostGIS_Database	SDE_Master_Database
Description:	Local clone of UNAMID database	Central UNAMID ArcSDE geodatabase
Connection Parameters		
Namespace:	http://localhost:8080/geoserver	http://localhost:8080/geoserver
Database type:	postgis	arcsde
Server name or IP address:	localhost	unamid-elf-sde1
Port:	5432	8181
Instance name:	MasterThesis	MasterDB
User:	postgres	sde
Password:	*******	***

….

- Creating layers from the store. These layers are eventually used for publication in the map.

These steps are mandatory if a layer containing self-generated geodata is to be used in the webmapping application and are prepared in Geoserver's integral web interface http://localhost:8080/geoserver/web/. The layers are called from the server by using a HTTP protocol. This process does not refer to base maps which are available by specifying

the source URI and declaring a layer variable (*3.6.5.2 Web Map Service in Java Script*). Layers are the prerequisites of any web based application and constitute its geoinformational content. Once the step of publishing the layers in GeoServer is successfully accomplished, there is need to develop the webpage. The webpage contains all details that constitute its final layout. Its construction requires the languages JavaScript and html. *Appendix 2 (HTML)* and *Appendix 3 (JavaScript)* contain the full source code of the webpage. In the next paragraphs, only the quintessential concepts will be introduced.

To get a thorough overview how this code constructs the webpage, *Figure 5* first displays the heart of SIRS; the client-side web browser, zooming into the UNAMID headquarters in El-Fasher in North Darfur. The webpage has four dynamic elements; the map, the editing container, the feature display container and the legend container. These elements all use OGC-standards to be displayed, i.e. WMS, WFS-T, GetMap, GetFeatureInfo, GetFeature, GetLegendGraphic, DescribeFeatureType. These standards receive most attention in the following chapters.

In order to understand SIRS's complexity, it is helpful to look at the application from two perspectives. Firstly, the composition of the visual components is brought to light. Secondly, the information flow unearths how the user delegates SIRS to perform requested operations.

Figure 5   **Illustration of Security Incident Reporting System (SIRS)**

3.6.1   Explanation of client browser

The only static element of the webpage is the header, i.e. SIRS logo (1), and the footer, i.e. Instructions and Disclaimer (12). All other elements are retrieved dynamically. SIRS is split into the following components:

- **Header (1)**

Showing the logo of GIS section and UNAMID

- **Legend (West Panel) (2)**
    o Retrieved through the OGC: *WMS GetLegendGraphic* operator

- **Map Panel (centre panel) (3)**

The map panel is the visual centrepiece of the application. It holds all the application's visual geographical content and the user's ability to constitute the map in his/her own way. The map panel consists of the following items:

    o *Base Layers (Public geoinformation) (4)*

    Google© Hybrid, Google© Terrain, Yahoo© Maps, OpenLayers WMS

    o *Non Base Layers (Mission-specific geoinformation) (5)*
      ➢ **WMS (rendered images)**

      Incidents, UNAMID camps and teamsites (symbology and polygon), Communal Police Centres and UNAMID battalion boundaries

      WMS are requested by the OGC: WMS GetMap standard and assembled by the OpenLayers.Layer.WMS constructor

      ➢ **WFS-T (source data) (6)**

      Incidents layer for INSERT, UPDATE and DELETE operations

      WFS-T is requested by the OGC: WFS GetFeature standard and assembled by the OpenLayers.Protocol.WFS and OpenLayers.Layer.Vector (parent object) constructor. The WFS is edited through the "Edit Incidents" panel (below).

      ➢ **Layer Switcher (7)**

      Offers the possibility to switch of overlay layers or change base layers

➢ **Buttons for user action (8)**

Options for GetFeatureInfo, Add or Modify incidents (Add and Modify incidents requires the further use of the Edit Incidents panel which hosts the attribute form for the features being manipulated

➢ **OpenLayers controls (9)**

Layer Switcher (OpenLayers.Control.LayerSwitcher), Panning (OpenLayers.Control.PanZoomBar), Zooming and Panning (OpenLayers.Control.NavToolbar) and Mouse Position (OpenLayers.Control.MousePosition)

- **Edit Incidents (East Panel) (10)**

Accommodates for the INSERT, UPDATE and DELETE operations of the incidents layer.

   o Retrieved through OGC: WFS DescribeFeatureType standard and edited through the states OpenLayers.State.Insert, Update and Delete. Features are saved in the database through the OpenLayers.Protocol.Commit command.

- **Feature Selection (South Panel) (11)**

Retrieves information about clicked features in the map and displays them at the bottom. The GetFeatureInfo operator points to all WMS overlays and thus retrieves information about all layers presented in the legend. This increases the body of information and is a desirable outcome.

   o Requested by the OGC: WMS GetFeatureInfo standard and assembled by the OpenLayers.Control.WMSGetFeatureInfo control

- **Footer (12)**

Containing instructions and disclaimer

3.6.2 Information flow of SIRS

Controls, whether visible or not, handle events and are triggered trough user actions. For instance, a button implementing a "Select Feature Control" (OpenLayers.Control.SelectFeature) selects a single vector feature from the WFS incidents layer on a click event. If a feature is selected it will be highlighted and the attribute information will pop up in the editing container.

This implies a two-fold user action. Firstly, the control has to be activated by pressing a button (this button is provided by the GeoExt.Action tool explained in "*3.6.7 GeoExt – Enhancing the visual façade*") and now the control listens to the second user action of selecting an incident in the map. The feature is then highlighted and the attributes show up in the attribute form by calling the WFS DescribeFeatureType standard. It requires the additional implementation of an event listener. OpenLayers.Layer.Vector (assembles the WFS-T) owns the event listener "beforeFeatureSelected". It triggers the JavaScript function "addEditorGrid" which in turn retrieves the information through the DescribeFeatureType operation. The result is the appearance of the attribute form plus all attributes of the selected feature. By selecting a feature, the user can now continue with other actions. These possibilities entail a deletion of the feature, modifying its attribute values or cancelling the action. A feature deletion initiates the state OpenLayers.State.DELETE and modifying attributes calls the state OpenLayers.State.UPDATE. The user confirmation finally submits the changes to the database. Adding incidents is organised in much the same way only that the OpenLayers.Control.DrawFeature control listens to the event "beforeFeatureAdded" and saves the feature by calling the state OpenLayers.State.INSERT.

A notable difference here is the request to get information about the features. This is in contrast to adding, updating and deleting features not implemented by the WFS but the WMS. As such, feature information is displayed at the bottom of the page through the OGC:WMS GetFeatureInfo standard.

The information flow of the *four* possible operations and their events, i.e. adding, deleting, modifying and getting information about features, is displayed in the next figure.

Figure 6   Flow diagram of SIRS
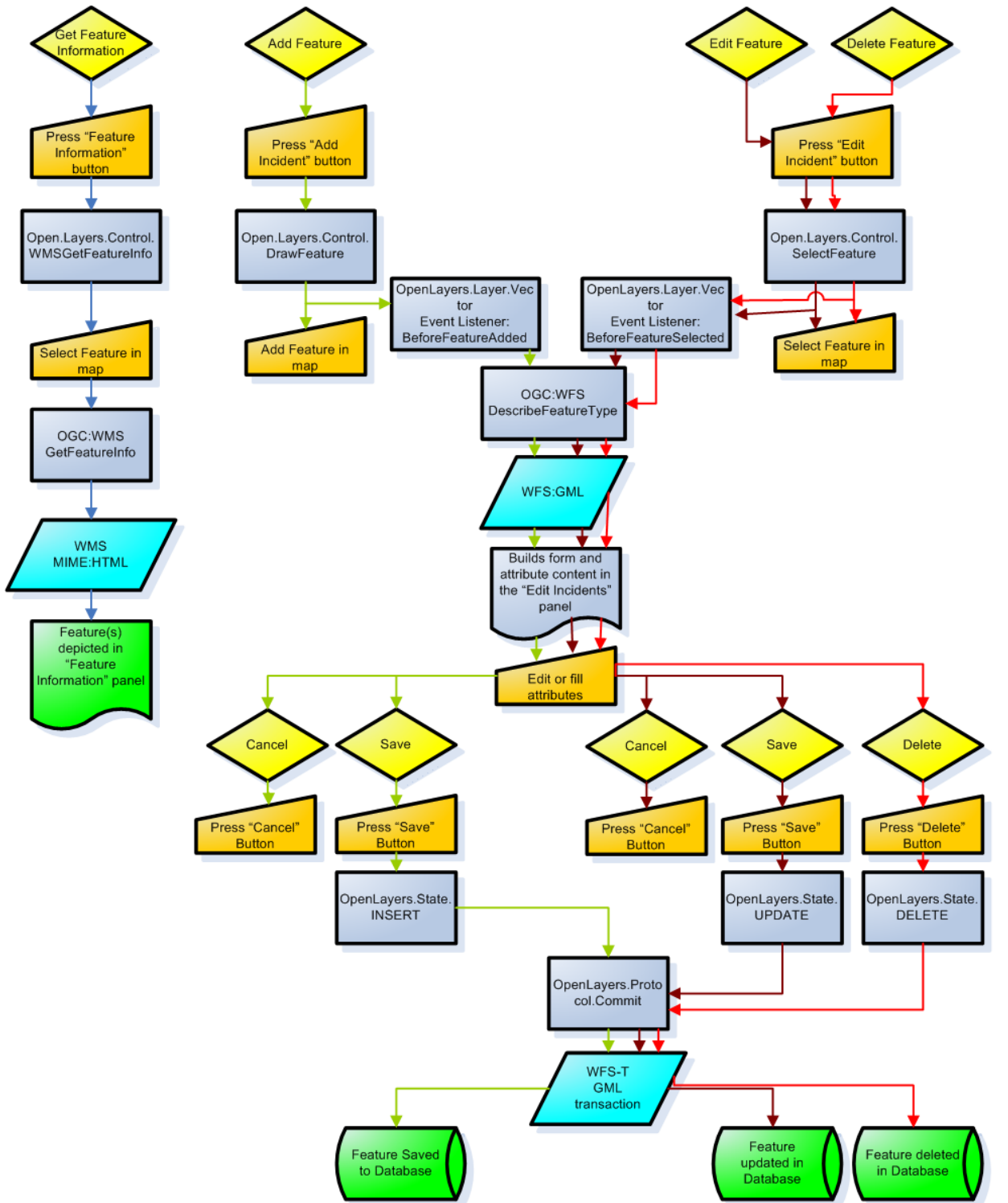
3.6.3   Map composition

The map window is the central element of the application. It displays all layers and is composed of base layers and overlays. It is a composite map that needs a common geographic coordinate reference system. It was outlined earlier that the biggest advantages of OpenGIS© is its ability to draw upon vast resources to be found on the Internet. Since resources such as Google© or Yahoo© are very rich in detail and up-do-date, especially so if you combine them, they constitute the foundation of the map and are called base layers in technical terms. The specific, mission-intern geoinformation are displayed as non-base layers and are called overlays.

At this stage, it is important to note that the decision to use Google© Hybrid necessitates a spherical Mercator projection and an enforcement of all other layers to be reprojected to the same coordinate reference system. Secondly, the WFS-T needs to be reprojected before features are submitted to the database. This is why the map projection needs to be defined in EPSG code 900913, which is the code for spherical Mercator. By choosing Google©, this is an inevitable enforcement which can be somewhat offset by choosing a different display projection. In SIRS this is implemented through the geographic projection (*3.6.5.1 Creating the map instance*).

3.6.3.1   Base layers

Google© Hybrid is the key base layer of the application to exploit the state-of-the-art high resolution satellite imagery of 60cm/pixel resolution. Technically, by calling the Google© layer, and all other external WMS, GeoServer becomes itself a client, further stressing the concept of distributed computing which was introduced in preceding chapters.

3.6.3.2   Spherical Mercator projection

As advantageous as the integration of Google© is, it also reveals some pitfalls in the choice of map parameters such as available projections. It is at any time a trade-off to accept these limitations or to reject the available web mapping service. For Darfur, however, the limitations of the spherical Mercator projection are largely mitigated. The region of interest is close to the equator and the equator is the projection's tangent. The tangent is where the developable surface meets the spherical representation of the earth (*Figure 7*).

The developable surface is applied to transform the shape of the earth into a (not yet) two-dimensional surface and can take on a cylindrical, conical or planar shape. In cylindrical and conical projections, the tangent is also the only line with no distortion (this may also be two lines which are then referred to as secants). In Darfur, the spherical Mercator projection is used no further than 20 degrees north. This close proximity to the equator alleviates most of the projection's disadvantages.

Figure 7   The cylindrical Mercator projection

The Mercator projection is named after the Flemish cartographer Gerardus Mercator, or Gerard Cremer as his real name was. His well-known projection is still used today for various purposes. Its dominance of use is grounded in its ability to show direction without distortion. Hence, any line on the map is a loxodrome, i.e. it shows its true direction in angular units in relation to the North Pole. When two points are connected, it will show the bearing as to how to reach that destination. This trait provides an ideal foundation for navigational purposes where the projection still receives most of its attention.

The projection also displays the true shape of objects (conformal). However, it largely falsifies the area of countries and this is also the reason for many misconceptions about the sizes of countries to this day. The further north one is on the map, the bigger the countries appear. As a matter of fact, this projection should not be used above 80 degrees north. The poles cannot be depicted as can be seen on the left illustration since they lie in infinity. The two-dimensional projection and its falsification can also be seen immediately in the next figure.

Figure 8 evidently displays the distortions given by the Mercator projection. The distance between latitudes continuously increases from the equator towards the poles. After eighty degrees north, this falsification becomes intolerable and should not be displayed. Here, it is only displayed to stress Mercator's disadvantage.

Figure 8   **The two-dimensional Mercator projection**
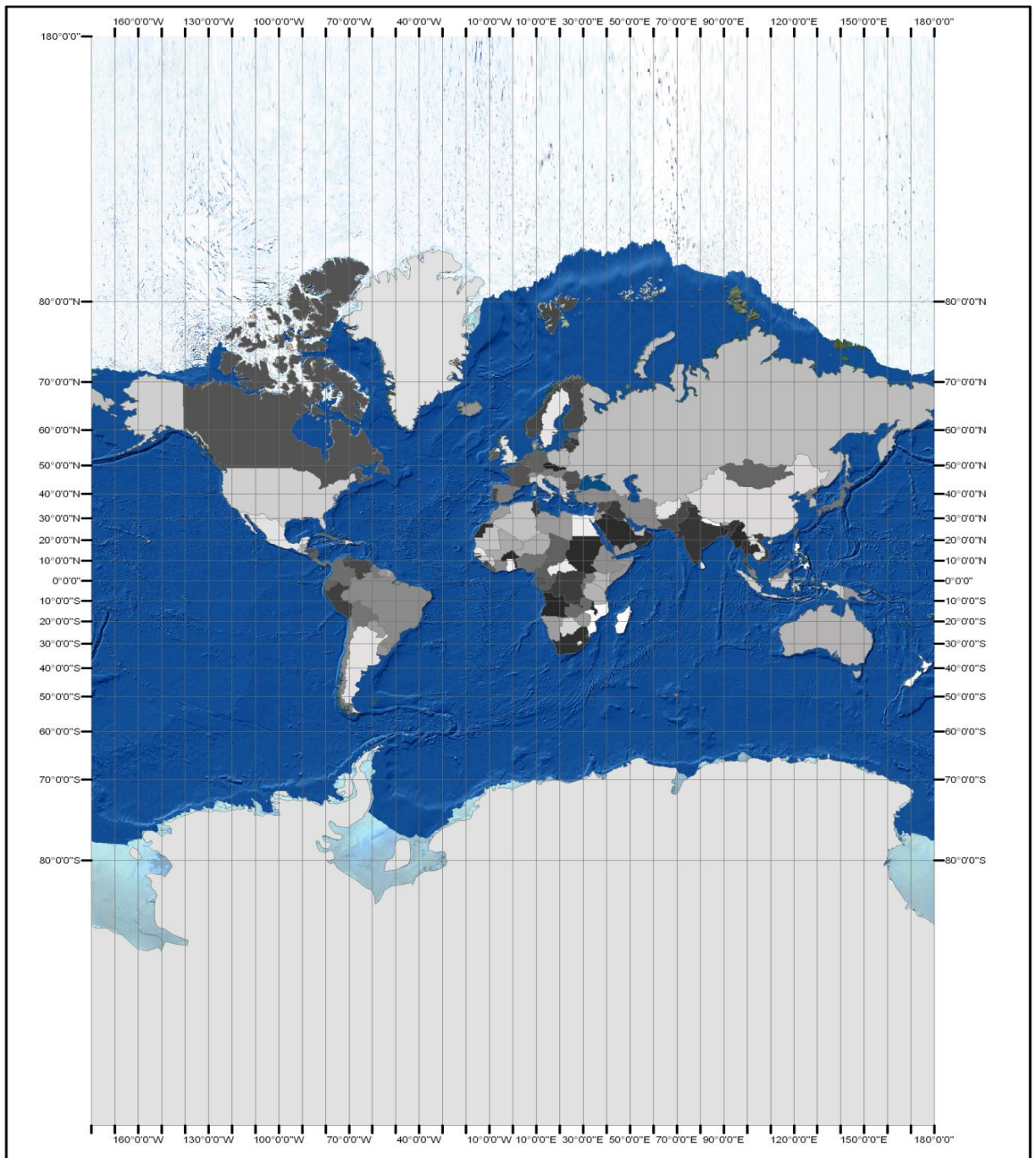
As the name spherical implies, the earth is actually treated as a sphere and not an ellipsoid. Any point on the globe has the exact distance to the centre of earth, which is at 6378.137 km. For many purposes this is fine. However, it is well-known that the earth approximates an ellipsoid, though the difference in axes is at less than 0.34% (1/300) fairly small. Additionally, it completely neglects the deformed true shape of the earth, known as the geoid. The geoid resembles more a potato-shape than an exact ellipsoid. This neglect can accumulate in wrong coordinates amounting to several hundred meters of misinterpretation. This error gets worse with increasing distance to the projection's tangent. One should always be aware of such projectional deficiencies. Be that as it may, for this application its vicinity to the equator limits such pitfalls and can in further chapters be neglected. Furthermore, positioning errors are much easier to accept in a security incidents reporting system than in, for instance, surveying.

According to EPSG definitions, which are the central means of projection definitions used in open source today, the code for spherical Mercator reads as follows:

```
PROJCS["Mercator_1SP",GEOGCS["Geographic Coordinate
System",DATUM["GOOGLE",SPHEROID["Sphere Radius 6378137
m",6378137,0]],PRIMEM["Greenwich",0],UNIT["degree",0.0174532925199433]],PROJECTION["Mercator
_1SP"],PARAMETER["scale_factor",1],PARAMETER["central_meridian",0],PARAMETER["latitude_of_o
rigin",0],PARAMETER["false_easting",0],PARAMETER["false_northing",0],UNIT["Meter",1]]
```

These parameters, offering no real surprise to geographers accustomed to map projections, are summarized as EPSG code 900913, 3857 or 102113. These codes can be used interchangeably and only occur threefold because there was uncoordinated development upon its implementation.

3.6.3.3 Non-Base Layers (Overlays)

The overlays display the actual geoinformation of the peace mission. All layers (except the WFS-T incident layer) are displayed as a Web Map Service. An overlay layer is determined by two keywords; the WMS-specific parameter "transparent" (base layers cannot be transparent) and the OpenLayers-specific parameter "isBaseLayer". Both parameters are Boolean in nature and determine the layer's hierarchy in terms of base and non-base layers.

3.6.4 Web Map Service (WMS)

Web Map Services constitute the richness of the map content. If the WFS-T ensures the editable vertical integration of database and client, WMS put this data in its broader visual perspective.

A WMS produces a georeferenced image and has three available operations:

- GetCapabilities
- GetMap
- GetFetaureInfo

To retrieve service-level metadata and to see what content and acceptable request parameters a WMS offers, GetCapabilities is implemented. GetMap actually requests the map. GetFeatureInfo retrieves information about particular coordinates in the map and returns text information in a specified format (implemented in the "Feature Selection" container Number 11, *Figure 5, p. 41*). GetCapabilities and GetMap are *required* operations of every WMS, only GetFeatureInfo is an *optional* operation. For the implementation of SIRS all three operations are supported.

3.6.4.1 WMS GetCapabilities Request

All WMS operators use a URL to invoke the request and elicit the response from the server. A minimalistic GetCapabilities URL includes the service type and the request name parameter. As can be seen in *Table 1*, these parameters are mandatory.

Table 1 GetCapabilities parameters

Request Parameter	Required/ Optional	Description
VERSION=version	O	Request version
SERVICE=WMS	R	Service type
REQUEST=GetCapablities	R	Request name
UPDATESEQUENCE=string	O	Sequence number or string for cache control

Source: http://portal.opengeospatial.org/files/index.php?artifact_id=1081&version=1&format=pdf ; p. 21

In order to get the metadata of the WMS, a GetCapabilities query for the incident reporting system contains the following parameters:

http://localhost:8080/geoserver/wfs?request=GetCapabilities&service=WFS&version=1.0.0&namespace=MasterThesis

This HTTP-GET request returns a XML-document specifying metadata information about the author, cost, available WMS and WFS operations, layers and their bounding boxes and projections, spatial, comparison and arithmetic operators and functions that are available for GIS analyses for the workspace "MasterThesis". The workspace is a layer container for GeoServer's published layers. The XML-response can be fully accessed in "*Appendix 5 GetCapabilities document for SIRS*", p. 105.

A URI request is always a GET-request in contrast to a POST-request which may request the same information, yet encoded in a XML document that is delivered to the server. In other words, GET is a simple URL to which additional parameters are appended in order to elicit a valid response. HTTP POST, on the other hand, attaches a request document, usually to the URL in which more complex requests can be postulated. The main difference is a limitation of the GET-request to 265 characters whereas the POST-request has no such limitation. SIRS uses a GET-request for all WMS requests. For more complex and selective queries like the WFS-T protocol, there is also an implementation of POST-requests.

3.6.4.2   WMS GetMap Request

The GetCapabilities document serves as a good overview for the capabilities of all layers contained in the workspace. However, the true visual component, i.e. the retrieval of the map, is done by the GetMap operator. This operation retrieves the overlays through a HTTP-GET request.

The HTTP-request *must* contain additional information about layers, styles, projection source, bounding box, width, height and format of the output. *Table 2* provides an overview of all required and optional parameters of a WMS GetMap request.

Table 2 **WMS GetMap parameters**

Request Parameter	Required/ Optional	Description
VERSION=version	R	Request version.
REQUEST=GetMap	R	Request name.
LAYERS=layer_list	R	Comma-separated list of one or more map layers. Optional if SLD parameter is present.
STYLES=style_list	R	Comma-separated list of one rendering style per requested layer. Optional if SLD parameter is present.
SRS=namespace:identifier	R	Spatial Reference System.
BBOX=minx,miny,maxx,maxy	R	Bounding box corners (lower left, upper right) in SRS units.
WIDTH=output_width	R	Width in pixels of map picture.
HEIGHT=output_height	R	Height in pixels of map picture.
FORMAT=output_format	R	Output format of map.
TRANSPARENT=TRUE|FALSE	O	Background transparency of map (default=FALSE).
BGCOLOR=color_value	O	Hexadecimal red-green-blue color value for the background color (default=0xFFFFFF).
EXCEPTIONS=exception_format	O	The format in which exceptions are to be reported by the WMS (default=SE_XML).
TIME=time	O	Time value of layer desired.
ELEVATION=elevation	O	Elevation of layer desired.
Other sample dimension(s)	O	Value of other dimensions as appropriate.
Vendor-specific parameters	O	Optional experimental parameters.
The following parameters are used only with Web Map Services that support the Styled Layer Descriptor specification [3].		
SLD=styled_layer_descriptor_URL	O	URL of Styled Layer Descriptor (as defined in SLD Specification).
WFS=web_feature_service_URL	O	URL of Web Feature Service providing features to be symbolized using SLD.

Source: http://portal.opengeospatial.org/files/index.php?artifact_id=1081&version=1&format=pdf ; p. 33

A valid WMS GetMap request that is fired for the display of the incident overlay layer looks like the following:

http://localhost:8080/geoserver/wms?REQUEST=GetMap&VERSION=1.1.1&LAYERS=MasterThesis:incidence_occurrences&styles=&SRS=EPSG:900913&BBOX=2295332.188819,1160395.193045,3464512.97326,1784121.343741&WIDTH=600&HEIGHT=300&FORMAT=image/png

This example also provides good illustration as to the reserved characters in the http query; "?" for separating server address from parameters,"&" for division of parameters,"=" for separation between name and value of parameter,"/" as separator of MIME type and

subtype (image/png),"¨" as separator of workspace and layer as well as value of SRS and "," for list values (WMS Specifications 2002, p. 11-12).

In a web browser this returns the incidence layer in an image format, as the next illustration discloses.

Figure 9   **Result of WMS GetMap request**

The illustration also reveals a symbology that is not inherently present but needs to be constructed. All information *per se* lacks a visual representation and is initially just a coordinate. To symbolize the incidents and all other layers, the application implements another OGC standard; Styled Layer Descriptor (SLD).

3.6.4.3   WMS Styled Layer Descriptor (SLD)

At first, geospatial data is no different to other data in that patterns have to be surfaced. Raw data alone is most of the times not able to present any thorough meaning to the audience. Geodata bears in it a geographic component and it is this locational attribute that differentiates it from other forms of information. The data's location is best visualized in a map and the map can convey the underlying pattern better than any careful investigation of coordinates. The human mind needs some form of abstraction to get the full picture of the data being analysed.

Secondly, and also very important, geodata has no intrinsic information about the visualization of its objects. For this reason, visualization involves a process of assigning symbols to layers and within it classes or objects. In GeoServer this is accomplished by the Styled Layer Descriptor (SLD). SLD is a XML-based markup language containing all information as to how to present its geoinformation. A markup language refers to an encoding of content in a way that is *self-explanatory*, *unique* and *system-independent* (Fisher 2005-2009; p. 1). XML is self-explanatory because it not only offers the content but also how this content is supposed to be read (markup).

The content, expressed by elements, is wrapped in tags. These tags are declared in namespaces, pointing to a webpage where the unique definitions are referenced. Thus, the namespace offers access to an (at least theoretically) infinite number of elements (extensible). Every community, GIS, physics, maths, biology, can define its own framework of communication. For instance, the WFS references three normative namespace definitions; WFS, GML and OGC (WFS Specifications; p. 27). [5] System-independence implies full readability of XML for different operating systems and software applications. XML is both machine-readable and human-readable.

Hence, unlike customary desktop GIS applications, the proper styling of geodata in GeoServer requires a computer language. The advantages of such an approach is ease of

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[5] http://www.opengeospatial.net/wfs http://www.opengeospatial.net/gml
http://www.opengeospatial.net/ogc

replication, use for other projects and a good integration with existing styles offered by open source projects from OGC or OpenStreetMap. The disadvantages are an often laborious, error-prone and time-consuming symbology.

A complete outline of the SLD file can be found in "*Appendix 4   Styled Layer Descriptor for the symbology of the incidents dataset*", p. 99. At this point only the vital components will be briefly discussed.

The XML file has a wrapper declaring that the file contains the XML language and that it is of nature StyledLayerDescriptor. In this wrapper all other necessary information about the symbology content is written.

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<StyledLayerDescriptor version="1.0.0">SYMBOLOGY CONTENT</StyledLayerDescriptor>
```

Essential part of the information contained within this wrapper are the namespaces. For SLD they point to the OGC namespace:

```
xmlns:ogc="http://www.opengis.net/ogc"
```

xmlns refers to XML namespace and *ogc* is the abbreviation used for references in the subsequent part of the XML file. The URI defines where the namespace is to be found. The OGC namespace provides access to our attribute selection of the dataset. With the SLD file GeoServer will define the different symbols according to the type of incidents (as specified in the incident column attribute). As an example, the incident "Abduction" found in the "incident" column of the "incidence_occurrences" dataset needs to be selected. In OGC standards this is defined by the ogc:filter:

```
<Rule>
  <Name>Abduction</Name>
   <ogc:Filter>
     <ogc:PropertyIsEqualTo>
        <ogc:PropertyName>incident</ogc:PropertyName>
        <ogc:Literal>Abduction</ogc:Literal>
     </ogc:PropertyIsEqualTo>
   </ogc:Filter>
</Rule>
```

The filter looks up the incident data column and selects the "Abduction" rows through the "ogc:literal" object. The SQL equivalent for this attribute selection used in the database query is:

SELECT * from incidence_occurrences WHERE incident LIKE "Abduction"

After the selection, all abductions are symbolized by a graphic and a specified size which is defined as follows:

```
<PointSymbolizer>
  <Graphic>
    <ExternalGraphic>
      <OnlineResource
        xlink:type="simple"
        xlink:href="http://localhost:8080/geoserver/styles/images_incidents/abduction.png" />
      <Format>image/png</Format>
    </ExternalGraphic>
    <Size>22</Size>
  </Graphic>
</PointSymbolizer>
```

These steps are repeated until all incidents and all layers are accounted for leading to the following symbology illustration.

Figure 10   SLD symbology for the overlay (mission-specific) layers
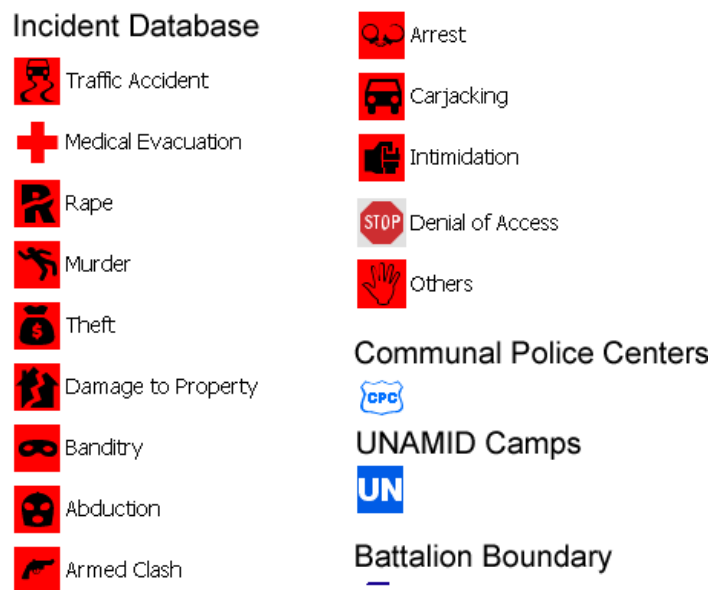
The SLD files are subsequently uploaded through the GeoServer web user interface, after navigating to "Data" – "Styles" and creating a new style. After the style is assigned to the layer it will display the appropriate symbology on the map.

3.6.4.3.1 SLD GetLegendGraphic

Styled Layer Descriptors also add additional benefits to a WMS. There are a number of additional operations, only available for a SLD-enabled WMS, which can be triggered to extend information about the map service. These are:

- DescribeLayer
- GetLegendGraphic
- GetStyles
- PutStyles (WMS Specifications 2002; p. 15)

The GetLegendGraphic request can dynamically construct the legend with the specified symbology and is implemented in the western panel containing the legend information (Number 2, *Figure 5, p. 41*). The URL request for the incident layer legend looks like the following:

http://localhost:8080/geoserver/wms?TRANSPARENT=true&SERVICE=WMS&VERSION=1.1.1&REQUEST=GetLegendGraphic&EXCEPTIONS=application/vnd.ogc.se_xml&LAYER=MasterThesis:incidence_occurrences&SCALE=6933504.261314689&FORMAT=image/gif

This URL returns the legend image which is depicted in the Legend Panel of the webpage (Number 2*, Figure 5*).

At this stage, the implementation has finalized the second of the five requirements as outlined in the introduction; Provide up-to-date, accurate and information-rich maps. Following the reasoning that there is an abundance of existing geodata waiting to be integrated, the Google© and Yahoo© base layers have been chosen to complement the original purpose of the application. The overlays have also been added to the map. To

complete the second point of the requirement, that is query its data, a GetFeatureInfo request for the overlay maps has to be implemented.

3.6.4.4 WMS GetFeatureInfo Request

A GetFeatureInfo request is next to GetCapabilities and GetMap the third operation of a Web Map Service. As opposed to the GetCapabilities and GetMap requests, GetFeatureInfo is an *optional* element of a WMS and need not be implemented. As the name suggests, the map can be queried through initiating a click event in the map itself. This event triggers a request to the server that responds to it by returning the information about the selected object. There are ten parameters that a GET-request can specify, some are mandatory and some are optional. The following table provides an overview of these parameters.

Table 3   WMS GetFeatureInfo parameters

Request Parameter	Required/ Optional	Description
VERSION=version	R	Request version.
REQUEST=GetFeatureInfo	R	Request name.
<map_request_copy>	R	Partial copy of the Map request parameters that generated the map for which information is desired.
QUERY_LAYERS=layer_list	R	Comma-separated list of one or more layers to be queried.
INFO_FORMAT=output_format	O	Return format of feature information (MIME type).
FEATURE_COUNT=number	O	Number of features about which to return information (default=1).
X=pixel_column	R	X coordinate in pixels of feature (measured from upper left corner=0)
Y=pixel_row	R	Y coordinate in pixels of feature (measured from upper left corner=0)
EXCEPTIONS=exception_format	O	The format in which exceptions are to be reported by the WMS (default=application/vnd.ogc.se_xml).
Vendor-specific parameters	O	Optional experimental parameters.

Source: http://portal.opengeospatial.org/files/index.php?artifact_id=1081&version=1&format=pdf ; p. 40

A valid GetFeatureInfo request for SIRS looks similar to this and can be used as a URL in any web browser, given a running server environment:

http://localhost:8080/geoserver/wms?&SERVICE=WMS&VERSION=1.1.1&REQUEST=GetFeatureInfo&LAYERS=MasterThesis:incidence_occurrences,MasterThesis:camps_poly,MasterThesis:unamid_camps_point,MasterThesis:communal_police_center,MasterThesis:battalion_boundary&QUERY_LAYERS=MasterThesis:incidence_occurrences,MasterThesis:camps_poly,MasterThesis:unamid_camps_point,MasterThesis:communal_police_center,MasterThesis:battalion_boundary&STYLES=,,,,&BBOX=2040949.758732,738462.796987,

3718895.403347,2206053.739799&FEATURE_COUNT=10&HEIGHT=600&WIDTH=686&FORMAT=image/png&INFO_FORMAT=text/html&SRS=EPSG:900913&X=357&Y=232

This HTTP-GET request might at first be misleading since it actually contains an embedded GetMap request (the third parameter of *Table 3*). To disentangle the GetMap request from the GetFeatureInfo request, a clear representation of the pure GetFeatureInfo parameters for the incidence layer facilitates the comprehension of the OGC standard and not how it actually assembles its automated request:

VERSION:	1.1.1
REQUEST:	GetFeatureInfo
QUERY_LAYERS:	MasterThesis:incidence_occurrences
INFO_FORMAT:	text/html
X:	357
Y:	232

The content of this exemplary feature is requested as the MIME type "text/html". This output type is a display-friendly format, parsing the raw body of the response in a html table and presenting it in the "Feature Selection" container at the bottom of the webpage (Number 11, Figure 5*, p. 41)* (OpenLayers Homepage 2010).

The server responses the following HTML information:

Table 4   WMS GetFeatureInfo response

INCIDENCE_OCCURENCES

fid	org_type	incident	date_	time	location	ruralconcl	locality	state	source	remarks	victim	offender
incidence_occurences.129	Others	Banditry	10/07/10 00:00	1000	Mado	Mellit & Sayeh	Mellit	Northern Darfur		Road banditry		Armed men

The response delivers the selected feature instance at that position using an approximation. For this reason, the X, Y coordinates do not have to be exact map coordinates. It is essential to point out that the click event in the map points to the workspace "MasterThesis". This is why the above (fully automated) HTTP information request can retrieve multiple features from multiple layers. This is a desirable result by all means. It is in the best interest of SIRS to retrieve information not only from the incidents but also from all other complementary layers.

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It is also important to note that the protocols cannot be assembled by the user for its immense demand of knowledge of HTTP and OGC parameters. Even a flawless expert in OGC standards would need tremendous efforts to construct a request. For instance, this would entail a 7-line syntax for the GetFeatureInfo request of page *58*. The protocols and all other information transmitted must be concealed from the user. Under the hood, this is accomplished by OpenLayers, a JavaScript library that is able to do just that; hide all technical specifications from the user.

3.6.5   OpenLayers

OpenLayers is a geospatial JavaScript library to enable the creation of dynamic and interactive maps. In general terms, JavaScript integrates dynamic elements into web pages. It is a scripting language that is either embedded in the html-webpage through the tags '*<script type="text/javascript" > </script>*' or is called upon through definition of a source file, e.g. *src="master_thesis.js"*. In this example, it references an additional JavaScript file for inclusion in the same directory when it builds the webpage. The latter approach is predominantly chosen for SIRS (*Appendix 3 JavaScript source code of SIRS, p. 90*).

JavaScript was invented to code separate information disentangled from HTML into a webpage. Today, HTML should only contain the static document structure and following from this, its dynamic components should be outsourced. The most dominant implementation in order to achieve this is JavaScript. It is a web-enhancing technology turning static HTML into an "engaging, interactive and intelligent experience" (Goodman et al. 2004; p. vii-p.3). This complies with the need of SIRS to be interactive in order to harvest the best possible quality of geoinformation.

The application needs to handle an abundance of operations. Overlays and base layers need to be requested, information needs to be sent back and forth from server and client. The most rewarding experience for the user, however, is the interactivity OpenLayers provides with its dynamic map construction. In order to achieve this, the map instance has to be

created. Furthermore, layers and controls (such as zooming) need to be added. These processes all happen in the JavaScript environment.

3.6.5.1   Creating the map instance

The map instance is created by defining the map parameters and initializing the map using the OpenLayers constructor "new OpenLayers.Map". The parameters[6] define geographic properties such as projection, spatial extent, map units, etc. The JavaScript code first defines the parameters of the map instance and then initialises the map.

```
var options = {
        projection: new OpenLayers.Projection("EPSG:900913"),        // = spherical Mercator
        displayProjection: new OpenLayers.Projection("EPSG:4326"),  // = geographic projection
        units: "m",
        maxResolution: 78271.51695,
        maxExtent: new OpenLayers.Bounds(2295332.188819, 1160395.193045, 3464512.97326,
        1784121.343741)
        };

var map = new OpenLayers.Map('map', options);
```

In itself, the map instance does neither contain information nor functionality. To complement the map, map controls and layers are added. The controls constitute visible tools (Number 9, *Figure 5, p. 41*) such as the Pan-Zoom bar (Openlayers.Control. PanZoomBar), the navigation tool (OpenLayers.Control.NavToolbar), the layer switcher (Openlayers.Control.LayerSwitcher) and the coordinate display (OpenLayers. Control.MousePosition). There is also an invisible control for keyboard shortcuts (OpenLayers.Control.KeyboardDefaults). The layers are retrieved through the WMS constructor.

---

[6] For a full list of map parameters visit http://dev.openlayers.org/docs/files/OpenLayers/Map-js.html

3.6.5.2   Web Map Service in JavaScript

WMS are simpler to handle than WFS since they do not have to perform any other operation than to be visualised. Here, the distinction between base and non-base layers is important again. For, base layers are retrieved through distributed means from other servers. As mentioned in chapter "*3.6.3.1 Base layers*" the server becomes itself a client by requesting WMS from other sources.

The non-base layers, or overlays, contain the mission-intern geographic information. These overlays are called by the OpenLayers.Layer.WMS constructor which also contains information where the data is found and how it is to be presented. The WMS for the UNAMID camps and teamsites looks like the following:

```
var camps_poly = new OpenLayers.Layer.WMS(
        "UNAMID Camps Polygon",
        "http://localhost:8080/geoserver/wms?",
        {
         layers: 'MasterThesis:camps_poly',
         styles: '',
         srs: 'EPSG:4326',
         format: 'image/png',
         transparent: true
        },
        {
         'singleTile': true, 'opacity': 0.9, 'isBaseLayer': false, 'wrapDateLine': true
        }
    );
```

Base layers take a different approach and are initialised through a URL pointer and an OpenLayers.Layer constructor specifying the parameters of the remote WMS. For Google© Hybrid this is defined as follows:

```
<script src =
"http://maps.google.com/maps?file=api&amp;v=2&amp;key=ABQIAAAA9XNhd8q0UdwNC7YS
O4YZghSPUCi5aRYVveCcVYxzezM4iaj_gxQ9t-UajFL70jfcpquH5l1IJ-Zyyw"></script>

var gsat = new OpenLayers.Layer.Google(
        "Google Hybrid",
        {type: G_HYBRID_MAP, sphericalMercator: true}
```

The function "Ext.onReady(function({…})" defines all these layers until base layers, overlays and the editable incidence layer are complete and adds them first to the map object "map.AddLayers([…])" and then to the map panel "GeoExt.MapPanel({…})". Altogether, they constitute the pivotal map element of SIRS (Number 3, *Figure 5,* p. 41).

The incident reporting system has now implemented all three operations of the WMS implementation specifications and disguised them in its OpenLayers framework. These utilisations fulfil two of the four conditions outlined in the SIRS requirements, i.e. display and query geodata. However, it is now also evident that, by having exhausted all possible operations of WMS, further OGC web services need to be included to also be able to manipulate data. To edit geodata, only the WFS-T protocol will achieve the necessary results. This introduces three new concepts; the Web Feature Service, its transactional protocol and GML. These concepts will be the main focus of the coming chapters.

3.6.6   Transactional Web Feature Service – Editing Geodata

For information about features and their information to be displayed, a WMS still serves the purpose very well. Nevertheless, WMS only deal with rendered images. In order to truly edit geodata, however, a Web Map Service will soon reach its limit and has to be abandoned for the transactional Web Feature Service (WFS-T). Since a map is not the geodata itself but a representation of it by an image, the WFS has to be called upon to get more options about selection and editing of single features. Following from this, WFS can best be thought of as getting the "source code" of geodata (GeoServer Homepage 2010). This is further illustrated in *Figure 11*. The implemented services for SIRS are highlighted in green.

Figure 11   **OGC Web Services Architecture**
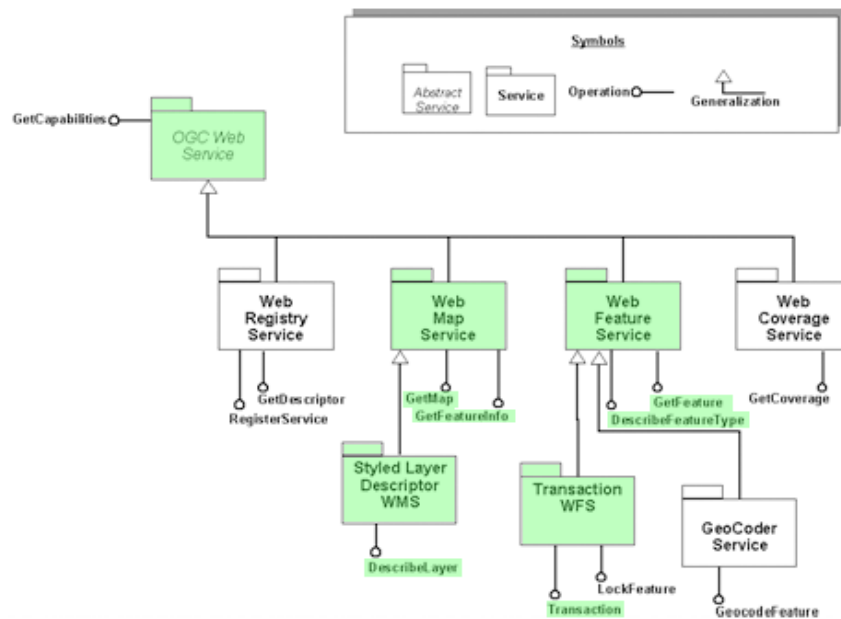
Source: Web Feature Service Specifications; page 15

The illustration shows the focus of WMS on layer depiction and descriptive information whereas the WFS truly fetches and edits geodata by being able to change and write geoinformation back to its source. The WFS specification document stresses this advance by taking "the next logical step (from WMS to WFS, ed.) for data access and manipulation operations on geographic features using HTTP as the distributed computing platform". This

distributed access stresses the large opportunities to "combine, use and manage geodata" (WFS Specifications 2005; p. 5).

The implementation of a Web Feature Service is thus a higher level exchange of geographic information on the Internet. For WMS, all geographic information could be processed via images or text. To get the source data, however, the WFS requires the geographical markup language to be utilized. GML is used to transfer the data between the client and the server and vice versa. This information might be the *display* of the whole WFS-T through the GetFeature operator or the *modification* of a feature through an INSERT, UPDATE or DELETE command.

3.6.6.1   Geographical Markup Language

Like SLD introduced in earlier chapters, GML is a XML based markup language that conveys content and its explanation/description of the data. GML derives its validity from the ISO 19100 standard series (GML Specifications 2007; p. 5). These documents outline the "feature" as the pivotal digital representation of a real world phenomenon. Similar to many activities in geographic information science, the focus of GML on features is a central paradigm to reduce the 'real world' into digital information. At its very heart, a vast proportion of GIS is preoccupied with translating natural phenomena into simplified, structured and thematic information and by processing information through many levels of abstraction. In its final stage, its digital representation, GI has lost and filtered out vast quantities of its true representation. The sheer infinite amount of information for a city, for instance, with its roads, houses, infrastructure, inhabitants, shops, restaurants, parks, venues, programmes, tours, etc. is in a small scale map reduced to a point containing no or very limited attributional information. This concept stretches solidly through most levels and aspects of GIS and so it does, looking at the focus on features, in GML, too.

A geographic feature, representing a location relative to the Earth, bears a geometry-valued property. In GML the distinction between features and geometries is distinctive and clear-cut. A feature can best be seen as an object representing a physical entity (Wikipedia 2011; GML). Its geometry is a sub-property of the feature itself. For this reason, a feature may or

may not have a geometric property. Both objects, feature and geometry must be seen as two separate entities.

3.6.6.2 WFS DescribeFeatureType

In order to shed more light on the distinction of both terms, a look at the application schema of the incidence layer clarifies the differences. The incidents layer is the only layer retrieving actual geographical data (source data). The application schema is called by the following URL:

http://localhost:8080/geoserver/wfs/DescribeFeatureType?version=1.1.0&typename=MasterThesis:incidence _occurrences

This request asks the server to respond the exact composition of the feature type it services. The DescribeFeatureType, along with GetCapabilities and GetFeature, is one of the three mandatory operators, *every* WFS has to support. The server responds a XML-document which is depicted in *Figure 12*.

This XML document reveals the idiosyncratic SIRS schema "incidence_occurrencesType". The schema is a composite of three GML classes; gml:_Feature, gml:AbstractFeatureType and gml:PointPropertyType. Together, these classes are used to fit the geometric point data for the incidents into its transmittable skeleton. At the same time, the features are collected from the server and displayed by the client in a standardized and interoperable fashion that all parties are able to understand. The schema is the literal straightjacket that forces the information to be consistent with its pre-defined structure. It is this prerequisite that qualifies the data to be labelled with the term interoperability.

Figure 12   WFS DescribeFeatureType response

```xml
<?xml version="1.0" encoding="UTF-8" ?>
- <xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
    xmlns:MasterThesis="http://localhost:8080/geoserver/"
    xmlns:Openlayers_examples="http://localhost:8080/geoserver/www/openlayers/examples"
    xmlns:cite="http://www.opengeospatial.net/cite" xmlns:gml="http://www.opengis.net/gml"
    xmlns:it.geosolutions="http://www.geo-solutions.it" xmlns:nurc="http://www.nurc.nato.int"
    xmlns:sde="http://geoserver.sf.net" xmlns:sf="http://www.openplans.org/spearfish"
    xmlns:tiger="http://www.census.gov" xmlns:topp="http://www.openplans.org/topp" elementFormDefault="qualified"
    targetNamespace="http://localhost:8080/geoserver/">
    <xsd:import namespace="http://www.opengis.net/gml"
      schemaLocation="http://localhost:8080/geoserver/schemas/gml/3.1.1/base/gml.xsd" />
  - <xsd:complexType name="incidence_occurrencesType">
    - <xsd:complexContent>
      - <xsd:extension base="gml:AbstractFeatureType">
        - <xsd:sequence>
            <xsd:element maxOccurs="1" minOccurs="0" name="org_type" nillable="true" type="xsd:string" />
            <xsd:element maxOccurs="1" minOccurs="0" name="incident" nillable="true" type="xsd:string" />
            <xsd:element maxOccurs="1" minOccurs="0" name="date_" nillable="true" type="xsd:date" />
            <xsd:element maxOccurs="1" minOccurs="0" name="time" nillable="true" type="xsd:string" />
            <xsd:element maxOccurs="1" minOccurs="0" name="location" nillable="true" type="xsd:string" />
            <xsd:element maxOccurs="1" minOccurs="0" name="ruralconcl" nillable="true" type="xsd:string" />
            <xsd:element maxOccurs="1" minOccurs="0" name="locality" nillable="true" type="xsd:string" />
            <xsd:element maxOccurs="1" minOccurs="0" name="state" nillable="true" type="xsd:string" />
            <xsd:element maxOccurs="1" minOccurs="0" name="source" nillable="true" type="xsd:string" />
            <xsd:element maxOccurs="1" minOccurs="0" name="remarks" nillable="true" type="xsd:string" />
            <xsd:element maxOccurs="1" minOccurs="0" name="victim" nillable="true" type="xsd:string" />
            <xsd:element maxOccurs="1" minOccurs="0" name="offender" nillable="true" type="xsd:string" />
            <xsd:element maxOccurs="1" minOccurs="0" name="the_geom" nillable="true"
              type="gml:PointPropertyType" />
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
  <xsd:element name="incidence_occurrences" substitutionGroup="gml:_Feature"
    type="MasterThesis:incidence_occurrencesType" />
</xsd:schema>
```

Gml:_Feature is the superclass for all incidents and is of type gml:AbstractFeatureType. They are both abstract classes and provide a set of common properties. A concrete feature must hence adhere to the properties as outlined in these properties. Most of these properties are inherited in a cascading structure. Together, they construct all database requests in such a way that collects the entire feature. This entails all geometry and attribute properties as well as the important gml:id which is the database handle for the object by providing the unique identifier through the type gml:AbstractGMLType. *Figure 13* illustrates the GML framework of a feature.

Figure 13 **GML framework of a feature**
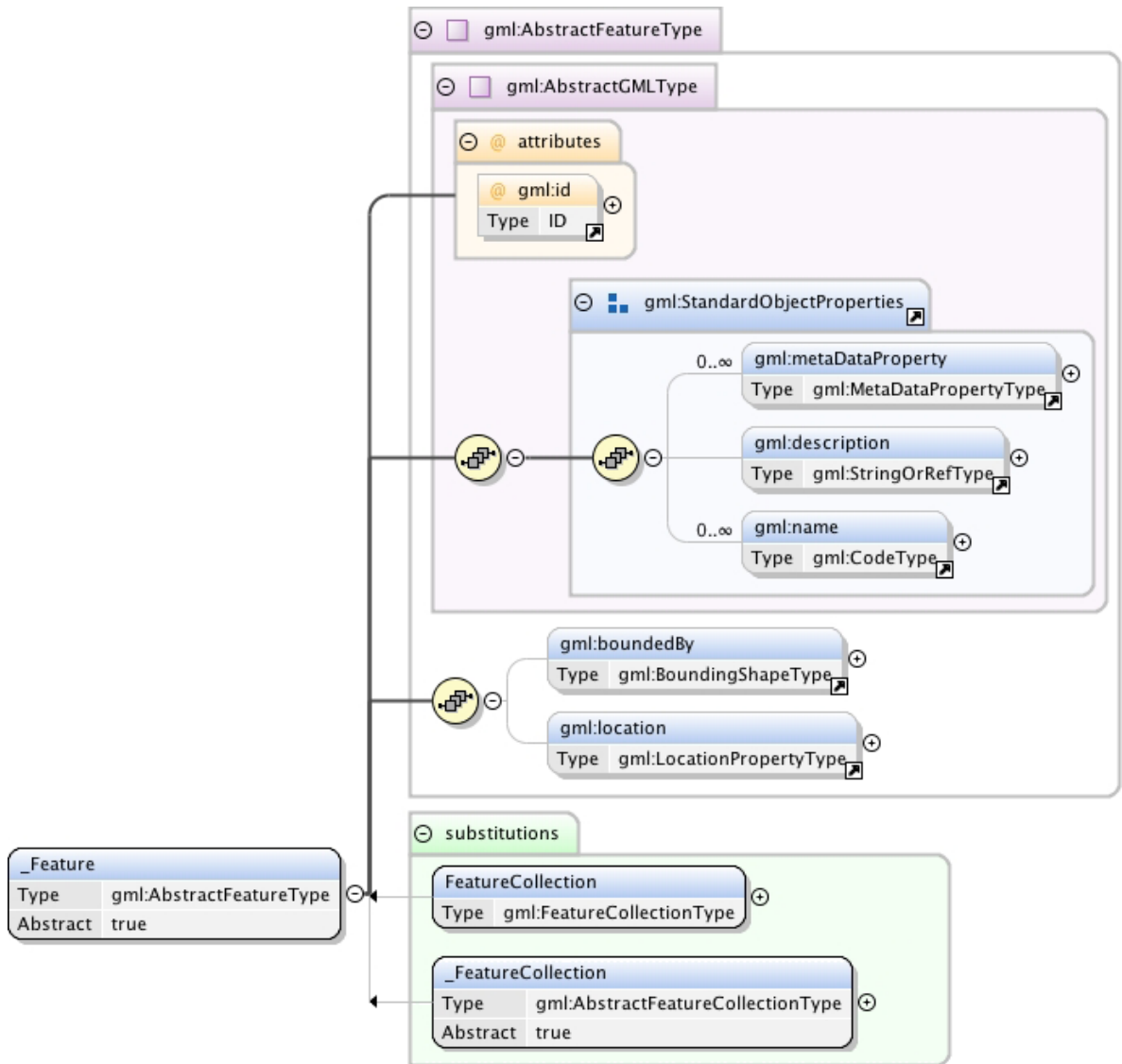
The class AbstractFeatureType provides the two specific elements for the geometric properties. Gml:boundedBy is primarily used as an index for rapid searching in a particular location. It is not used in SIRS and shows up as "null" in the WFS:GetFeature response (*Figure 15, p. 71*). To improve performance and scalability, this would be a further asset to incorporate in future developments.

Access to the location of the feature is given by the gml:location property (ISO Webpage 2010; Feature.xsd). Through its "_Geometry" element, it provides, as the abstract head,

access to *all* geometry elements of GML. Finally, "_AbstractGeometricPrimitiveType" is found as a substitution class of "_Geometry", which is the abstract 'destination' of the incidence objects. For, the geometry of the incidents are stored as points and are thus zero-dimensional geometric primitives represented by a latitude and longitude coordinate tuple.

The concrete type is the GML predefined "PointPropertyType" element associated with the geometry object type "Point". GML defines points in the "gml:point" property through single coordinate tuples. This is what the DescribeFeatureType response (*Figure 12, p. 67*) reveals in its last element of the feature. This point is found in the column "the_geom" of the PostGIS database (and "SHAPE" of the ArcSDE© database respectively).

The structure of GML emphasizes the division of feature and geography. Indeed, a feature remains, in absence of a geographic component, completely valid and coherent, even though in the context of the incidence application there is no reason to store non-geographic features.

The DescribeFeatureType operation helps to understand what a feature has to look like. Secondly, it is also the operator to construct the empty form for the editing container. In order to use this standard, the WFS-T first needs to be requested. This implies OpenLayers' need to assemble the protocol. Furthermore, OpenLayers also has to cater for the editing operations such as inserting, deleting or updating a feature. These editing capabilities are provided for by transferring the state of a feature.

3.6.6.3 **Web Feature Service in JavaScript**

To start with, the WFS needs to be specified and requested. This is done by defining a protocol that looks like the following:

```
var protocol = new OpenLayers.Protocol.WFS({
      url:  "http://localhost:8080/geoserver/wfs",
      outputFormat: "GML2",
      featureType: "incidence_occurrences",              // = feature dataset
      featurePrefix: "MasterThesis",                      // = workspace
      geometryName: "the_geom",                           // = geometry column
      version: "1.1.0",
      srsName: "EPSG:4326"
      })
```

As can be seen, the protocol is now a variable and is used to request the WFS. It is also the basis to perform changes on the underlying database through INSERT, UPDATE and DELETE operations. "OpenLayers.Protocol.WFS" creates a new WFS instance with the specified connection and content parameters.

To retrieve the data, i.e. visualise the content, the WFS GetFeature operation is called which passes the incidents in GML to the client. This process is automated in the beginning when the webpage is loaded through requesting the vector layer in JavaScript:

```
return new OpenLayers.Layer.Vector("Edit Incidents", {
      strategies: [new OpenLayers.Strategy.Fixed()],
      Visibility: true,
      projection: geographicProjection      // = new OpenLayers.Projection("EPSG:4326"),
                                             // defined as a global variable in App. 3
      protocol: protocol,                    // = WFS
      eventListeners: {…}                    // implements events such as attribute form
      }});                                   // requisition
```

3.6.6.4 **WFS GetFeature Request**

The transactional WFS, as collected through the OpenLayers.Layer.Vector and OpenLayers.Protocol.WFS constructors[7], displays the layer by initiating a WFS GetFeature POST request. The request is displayed in the following figure.

Figure 14 **WFS GetFeature POST request**

```
<wfs:getfeature xmlns:wfs="http://www.opengis.net/wfs" service="WFS" version="1.1.0"
outputFormat="GML2" xsi:schemaLocation="http://www.opengis.net/wfs http://schemas.opengis.net/wfs/1.1.0/wfs.xsd"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
<wfs:query typeName="incidence_occurrences" srsName="EPSG:4326"></wfs:query>
</wfs:getfeature>
```

The response provides good illustration why this might be referred to as the source data. As opposed to a rendered image, GML returns the features as a feature collection. *Figure 15* excerpts the first instance of the GML document.

Figure 15 **GML GetFeature response document**

```
<wfs:featurecollection xmlns="http://www.opengis.net/wfs" xmlns:wfs="http:
//www.opengis.net/wfs" xmlns:gml="http://www.opengis.net/gml" xmlns:MasterThesis="http:
//localhost:8080/geoserver/" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance" xsi:schemaLocation="http://localhost:8080/geoserver/ http://localhost:8080/geoserver
/wfs?service=WFS&version=1.0.0&request=DescribeFeatureType&
typeName=MasterThesis%3Aincidence_occurrences http://www.opengis.net/wfs http://localhost:8080
/geoserver/schemas/wfs/1.0.0/WFS-basic.xsd">
    <gml:boundedby>
        <gml:null>unknown</gml:null>
    </gml:boundedby>
    <gml:featuremember>
        <masterthesis:incidence_occurrences fid="incidence_occurrences.1">
            <masterthesis:org_type>UNAMID</masterthesis:org_type>
            <masterthesis:incident>Carjacking</masterthesis:incident>
            <masterthesis:date_>2009-06-05</masterthesis:date_>
            <masterthesis:location>Zalingei</masterthesis:location>
            <masterthesis:locality>Zalingei</masterthesis:locality>
            <masterthesis:state>West Darfur</masterthesis:state>
            <masterthesis:the_geom>
                <gml:point srsName="http://www.opengis.net/gml/srs/epsg.xml#4326">
                    <gml:coordinates xmlns:gml="http://www.opengis.net/gml" decimal="." cs="," ts="
                    ">23.45041063,12.96514186</gml:coordinates>
                </gml:point>
            </masterthesis:the_geom>
        </masterthesis:incidence_occurrences>
    </gml:featuremember>
    <gml:featuremember>
        <masterthesis:incidence_occurrences fid="incidence_occurrences.2">
            <masterthesis:org_type>UNAMID</masterthesis:org_type>
            <masterthesis:incident>Carjacking</masterthesis:incident>
            <masterthesis:date_>2009-08-02</masterthesis:date_>
            <masterthesis:location>Brangia</masterthesis:location>
            <masterthesis:locality>El Fasher</masterthesis:locality>
```

---

[7] This implementation, though it seems laborious to implement, is the recommended approach for OpenLayers 3.0 since the former OpenLayers.Layer.WFS will be removed in version 3.

This document is the foundation for the client to perform changes in the database. It needs to be able to select the feature's geometry and attributes so that the user may change values. The modification is then saved to the database by transferring the state of the feature.

3.6.6.5 Representational State Transfer (REST)

The request-response infrastructure between server and clients is also known as REST, Representational State Transfer. When the representation of an object is delivered to the client, the client transfers to a state. Upon each new object request, the state of the client is changed, i.e. transferred (ESRI Website 2011). The communication is stateless in nature, referring to communication that contains all information in its protocols and implying that no context is stored either on the server or client side (UCI 2011).

To modify the data structure, the WFS protocol implements the states INSERT, DELETE and UPDATE. The state property tells the protocol, i.e. the WFS-T, which operation is to be used and can take on the three following states:

```
OpenLayers.State.INSERT
OpenLayers.State.UPDATE
OpenLayers.State.DELETE
```

These states tell the protocol that the feature is ready to be transferred before finally initiating the command "protocol.commit" (line 174, *Appendix 3 JavaScript source code of SIRS).* This command has far-reaching implications for the database and provides deep insights about core principles of database technology in that one of the key advantages of databases are their ability to always be in a state of equilibrium. COMMIT is a transaction that ensures that the database is at all times consistent. Operations are only committed if this equilibrium can be sustained, otherwise changes are rolled back and refuted. This follows the ACID principle in which all database transactions must be *atomic*, *consistent*, *isolated* and *durable* (Fally 1994-2008; p. 27).

The application schema for the incidents as depicted in the DescribeFeatureType response (*Figure 12, p. 67*) defines how the feature is transmitted to the database. Every INSERT,

DELETE and UPDATE communication between the database and the client is wrapped in this local GML application schema and needs to remain within it. Every deviance will result in an exception report.

A closer look at an INSERT operation for an incident feature instance reveals how it is sent to the database for insertion. *Figure 16* outlines an exemplary feature that might be put in by a user. In the example, the coordinates are collected through a user click event in the map. The user need not worry about the exact digits of the coordinate tuple or reprojection. He/She just needs to fill the attribute form. The feature gets inserted when the user confirms by pressing the "Save" button.

Figure 16   Incidence GML feature instance

```xml
<wfs:transaction xmlns:wfs="http://www.opengis.net/wfs" service="WFS" version="1.1.0" xsi:schemaLocation="http:
//www.opengis.net/wfs http://schemas.opengis.net/wfs/1.1.0/wfs.xsd" xmlns:xsi="http://www.w3.org
/2001/XMLSchema-instance">
    <wfs:insert>
        <feature:incidence_occurrences xmlns:feature="http://localhost:8080/geoserver/">
            <feature:the_geom>
                <gml:point xmlns:gml="http://www.opengis.net/gml" srsName="EPSG:4326">
                    <gml:pos>23.541683157481 14.347592773094</gml:pos>
                </gml:point>
            </feature:the_geom>
            <feature:incident>Banditry</feature:incident>
            <feature:victim>Mr. A. Fergusson</feature:victim>
            <feature:offender>Unknown Perpetrators</feature:offender>
            <feature:org_type>UNAMID</feature:org_type>
            <feature:date>28/12/2010</feature:date>
            <feature:time>5 PM</feature:time>
            <feature:location>AMIS El-Fasher</feature:location>
            <feature:ruralconcl>El-Fasher/ZamZam</feature:ruralconcl>
            <feature:state>North Darfur</feature:state>
            <feature:locality>El-Fasher</feature:locality>
            <feature:source>CPC</feature:source>
            <feature:remarks>$250 and Mobile stolen</feature:remarks>
        </feature:incidence_occurrences>
    </wfs:insert>
</wfs:transaction>
```

The response of the server is a success protocol. *Figure 17* displays a successful insert operation. The bottom right corner of the figure shows a visual GeoExt Message box that notifies the user of the successful insert.

Figure 17   **Incidence INSERT success response**


```
<wfs:transactionresponse version="1.1.0" xsi:schemaLocation="http://www.opengis.net/wfs http://localhost:8080
/geoserver/schemas/wfs/1.1.0/wfs.xsd" xmlns:ogc="http://www.opengis.net/ogc" xmlns:tiger="http:
//www.census.gov" xmlns:cite="http://www.opengeospatial.net/cite" xmlns:nurc="http:
//www.nurc.nato.int" xmlns:sde="http://geoserver.sf.net" xmlns:wfs="http:                              :p:
//www.opengis.net/wfs" xmlns:topp="http://www.openplans.org/topp" xmlns:Openlayers_examples="http:
//localhost:8080/geoserver/www/openlayers/examples" xmlns:it.geosolutions="http://www.geo-
solutions.it" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:sf="http://www.openplans.org
/spearfish" xmlns:MasterThesis="http://localhost:8080/geoserver/" xmlns:ows="http:
//www.opengis.net/ows" xmlns:gml="http://www.opengis.net/gml" xmlns:xlink="http://www.w3.org/1999/xlink">
    <wfs:transactionsummary>
        <wfs:totalinserted>1</wfs:totalinserted>
        <wfs:totalupdated>0</wfs:totalupdated>
        <wfs:totaldeleted>0</wfs:totaldeleted>
    </wfs:transactionsummary>
    <wfs:transactionresults></wfs:transactionresults>
    <wfs:insertresults>
        <wfs:feature>
            <ogc:featureid fid="incidence_occurrences.142"></ogc:featureid>
        </wfs:feature>
    </wfs:insertresults>
</wfs:transactionresponse>
```
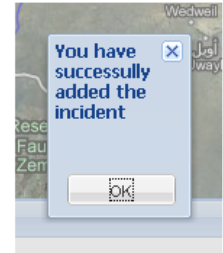
Such an INSERT operation, and this also applies to the UPDATE command, has to overcome one more obstacle. At this stage, any such operation would create a conflict between the map's and database's coordinate system. The WFS-T needs to be reprojected.

3.6.6.5.1   *WFS-T Reprojection*

The Google projection spherical Mercator is for all WMS, including the overlays, projected on-the-fly and is a readily available projection in the GeoServer environment. This is not true for the WFS-T, however, which would produce an out-of-bounds error if data was saved to the database. This enforces a reprojection for all click events (add, edit or delete incidents) from spherical Mercator (EPSG:900913) to the geographic projection (EPSG:4326). In JavaScript, this is the small but quintessential statement which first initializes the projections as global variables and subsequently transforms the feature's coordinates:

```
var sphericalMercator = new OpenLayers.Projection("EPSG:900913");
var geographicProjection = new OpenLayers.Projection("EPSG:4326");
        …
e.feature.geometry.transform(sphericalMercator,geographicProjection);        //(line 157, Appendix 3)
```

In summary, the application now contains all technological functionality. GeoServer, OGC and OpenLayers together combine powerful geospatial interoperability tools. GeoServer makes provision for the content of geodata, OGC defines how the data communication

takes place and OpenLayers hides the infrastructure from the user. The application has now an omnipotent mashup in place, providing detailed geographic information from numerous sources. In addition, internal data can be queried and the incidents database can be modified. Nevertheless, there is one disadvantage that reduces the effectiveness if solely relied on these components; visual appearance. OpenLayers has an under-developed visual component. SIRS overcomes this problem by including the extension GeoExt for OpenLayers.

3.6.7   GeoExt – Enhancing the visual façade

OpenLayers is a comprehensive application for geospatial and webmapping purposes. However, it lacks a framework to develop rich web applications. For this reason, the user interface has been further supported by integrating the GeoExt library. GeoExt is also a JavaScript library that combines OpenLayers with ExtJS. ExtJS provides many tools for web desktops and user interfaces. GeoExt improves the appearance of the website in the following areas:

- Structure the website into clearly defined containers (panels) for map, legend, editing and feature information

    The technical specifications are implemented through the following objects:
    - Ext.Panel
    - GeoExt.MapPanel
    - GeoExt.LegendPanel   that   holds   the   layers   in   the GeoExt.Data.LayerStore

- Ability of containers to be collapsed, allowing a full size view of the map
    - Set collapsible property of panels to true

- Offer transaction buttons for operations, e.g. feature selection, editing, saving, deleting or cancelling. These buttons trigger the implemented OGC standards.

  o OpenLayers controls are wrapped in GeoExt.Action objects (OpenLayers.Control.WMSGetFeatureInfo, OpenLayers.Control.SelectFeature, OpenLayers.Control.DrawFeature)

  o Editing buttons change the state (INSERT, DELETE, UPDATE) of the feature and commit the changes

- Provide an attribute form for feature editing and insertion

  o GeoExt.Ux.FeatureEditorGrid (exterior container)

  o GeoExt.Data.AttributeStore (the form itself fetched by the WFS:DescribeFeatureType standard)

- Inform the user of successful actions through message boxes, e.g. successful INSERT operation

  o Ext.Msg.Show

This extension turns the webpage into what can better be compared to a desktop application with easy to apply features and buttons. By including GeoExt, the operations are available at the touch of a button performing the actions that are specified in the JavaScript document without the need of extensive user knowledge. For instance, the collapsible window has become an accepted standard through mass dispersion. Any moderate computer literate will find it intuitive to understand the functionality of the webpage by providing similar and well-known features to be found in many other applications.

3.7   Security considerations

The beginning of chapter three briefly mentioned that the UN intranet already comes with a full-fledged security system in place. For this reason, any application that is bound and run within the Intranet service is also only accessible for registered domain users. The users of SIRS can be further limited to only grant permissions for key personnel. In a Windows Server environment this is done through creating users and roles in "Computer Management".

Secondly, GeoServer also provides a powerful security subsystem based on Spring Security, integrating the Acegi library that offers multi-level security support. In a nutshell, the security environment is like Windows administered through users and role allocation. These components secure and limit access through:

- **Service-level security**

  Service-level security refers to the OGC standards and allows for the restriction of use for WFS, WMS or WCS.

- **Layer-level security**

  GeoServer allows access to be constrained by layers. It is important to note that security-level and layer-level security cannot be combined and have to be seen as mutually exclusive.

- **REST security**

  REST security restricts the client-server communication by limiting access through the HTTP protocol. More specifically, the URI can be restricted and any matching pattern within this URI will prompt for authentication (GeoServer Homepage 2011).

These security levels all reside in the security folder of the GeoServer directory. In that directory all *.properties files, e.g. rest.properties, are found in which the roles and users can be added. It is perceived to be the most suited approach to use layer-level security which can precisely restrict classified layer information while the user still has full

functionality of the application. Nevertheless, the layers, particularly the overlays which constitute the mission-intern geoinformation, are only open to specified users.

In order to do so, the following information has to be amended to the layers.properties file:

"namespace.layer.permission=role"

In the context of this application, it contains the specific layer information:

"MasterThesis.incidence_occurrences.r.incidence_readers" for users only allowed to read the layer and

"MasterThesis.incidence_occurrences.w.incidence_writers" for users admitted to write the data.

Since the incidence layer is the only layer implementing a WFS-T, i.e. the editable layer, a distinction between viewers and writers only needs to be considered for this layer. All other layers just implement the "read" option. The properties of the layer-level security file are displayed next.

Table 5   Layer-level security properties

```
Layer.Properties
MasterThesis.incidence_occurrences.r=ROLE_INCIDENTS_DATABASE_READERS
mode=HIDE
MasterThesis.incidence_occurrences.w=ROLE_INCIDENTS_DATABASE_WRITERS
mode=HIDE
MasterThesis.camps_poly.r=ROLE_CAMPS_POLY_READERS
mode=HIDE
MasterThesis.camps_poly.r=ROLE_CAMPS_POINT_READERS
mode=HIDE
MasterThesis.camps_poly.r=ROLE_CPC_READERS
mode=HIDE
MasterThesis.camps_poly.r=ROLE_BATTALION_BOUNDARY_READERS
mode=HIDE
```

All layers have now a role defined. In one more step, a user has to be assigned the role to get access to the layer. This is accomplished by linking the users to the roles and defining a password for access. This is done in the User.Properties file which also resides in the

security folder of GeoServer. The next table illustrates an administration right configuration, allowing full access to SIRS.

Table 6 **User rights (admin)**

User.Properties
user=password,ROLE_INCIDENCE_READERS user =password,ROLE_INCDIDENCE_WRITERS user =password,ROLE_CAMPS_POLY_READERS user =password,ROLE_CAMPS_POINT_READERS user =password,ROLE_CAMPS_CPC_READERS user =password,ROLE_CAMPS_BATTALION_BOUNDARY_READERS

Any unauthorised access will result in the hide mode of GeoServer's published layers returning an exception report that the layer is not found.

Limited access and security constraints to avoid unauthorised access are quintessential if a distributed information sharing takes place. A multi-tier approach with various security measures additionally secures the web application. For, the use of intranet/internet to distribute resources exposes the system to an increased risk of interception.

4   Conclusion

Geographical information is a vital intelligence component for peacekeeping operations. Much of its usefulness depends on its accuracy, its timeliness and its accessibility. The more these criteria are fulfilled, the more it will augment security.

The technological application of the security incidence reporting system improves all three aspects. By developing an OpenGIS© infrastructure, the application facilitates the adoption of web based information sharing technologies. Taking this new road allows for the integration of freely available geoinformation on the Web. Maps like Google©, and Yahoo© are more up-do-date and of higher resolution than any peacekeeping mission could ever present by itself. Publicly available WMS layers are procured by distributed means and enrich the geoinformational base data. They serve the purpose of overcoming geoinformational deficiencies very effectively.

The third criterion, accessibility, is also largely enhanced by reaching remote locations in the mission area that contain only very basic infrastructure. By implementing the transactional WFS, security incidents can be easily administered, edited and visualised from any location within the mission area. Both standards, WMS as the informational fabric and WFS-T as the source data to maintain the database, open up new ways of data integration. Above all other considerations, enriched geoinformation should be the cardinal guide of application development for its ability to increase security through better decision-making.

The aims outlined in the introductory chapter have all been implemented. Nevertheless, the current system is only useful for the maintenance of the database. This should only be seen as the starting point for further development. The current stage is satisfactory for quick operational issues. At present, SIRS has its strongest advantages in displaying and editing security incidents. In order to be used for more strategic analyses, the system needs extensive advancements like filtering information by, for instance, incident type and/or date, report generation, sectoral comparison or evaluation, spatial or periodical

comprehension, etc. Geography loses importance with each higher-level analysis. The more strategic these analyses get, the more analysts are concerned with aggregation and accumulation, taking away the focus from the locational characteristic. A sustainable application that is able to integrate all of UNAMID's concerned sections will need to accommodate this trend and provide additional powerful tools for further analyses.

Interoperability increasingly infiltrates the GIS industry which was until very recently not known for being adept to incorporate standardisation methodologies. These developments are often criticised by the GIS community for its fear of being siphoned by mainstream internet technologies. This scepticism is often short-sighted. In many cases the GIS market can hugely benefit from such standards. The skills to spatially analyse problems will remain an important and independent area of research in its own right. By incorporating web based technologies, however, the advantages increase the efficacy of geoinformation, heighten its value and facilitate the adoption of geodata for distributed applications. The lowered barriers to geoinformational content should be welcomed. Information that is distributed and reused for numerous purposes has become an important pillar of the information society. As a public good, information achieves its greatest wealth through dissemination and not through segregation.

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20.1.2011

Appendix 1   UNAMID Mandate

Acting under Chapter VII of the Charter of the United Nations, the Security Council, by its resolution 1769 of 31 July 2007 decided that UNAMID is authorized to take the necessary action, in the areas of deployment of its forces and as it deems within its capabilities in order to:

i.   protect its personnel, facilities, installations and equipment, and to ensure the security and freedom of movement of its own personnel and humanitarian workers;

ii.   support early and effective implementation of the Darfur Peace Agreement, prevent the disruption of its implementation and armed attacks, and protect civilians, without prejudice to the responsibility of the Government of Sudan.

The Council also decided that the mandate of UNAMID shall be as set out in paragraphs 54 and 55 of the report of the Secretary-General and the Chairperson of the African Union Commission [S/2007/307/Rev.1] of 5 June 2007, namely as follows:

i.   To contribute to the restoration of necessary security conditions for the safe provision of humanitarian assistance and to facilitate full humanitarian access throughout Darfur;

ii.   To contribute to the protection of civilian populations under imminent threat of physical violence and prevent attacks against civilians, within its capability and areas of deployment, without prejudice to the responsibility of the Government of the Sudan;

iii. To monitor, observe compliance with and verify the implementation of various ceasefire agreements signed since 2004, as well as assist with the implementation of the Darfur Peace Agreement and any subsequent agreements;

iv.   To assist the political process in order to ensure that it is inclusive, and to support the African Union-United Nations joint mediation in its efforts to broaden and deepen commitment to the peace process;

v.   To contribute to a secure environment for economic reconstruction and development, as well as the sustainable return of internally displaced persons and refugees to their homes;

vi.   To contribute to the promotion of respect for and protection of human rights and fundamental freedoms in Darfur;

vii. To assist in the promotion of the rule of law in Darfur, including through support for strengthening an independent judiciary and the prison system, and assistance in the development and consolidation of the legal framework, in consultation with relevant Sudanese authorities;

viii. To monitor and report on the security situation at the Sudan's borders with Chad and the Central African Republic.

In order to achieve these broad goals, the operation's tasks would include the following:

Support for the peace process and good offices:

i.   To support the good offices of the African Union/United Nations Joint Special Representative for Darfur and the mediation efforts of the Special Envoys of the African Union and the United Nations;

ii.   To support and monitor the implementation of the Darfur Peace Agreement and subsequent agreements;

iii. To participate in and support the major bodies established by the Darfur Peace Agreement and any subsequent agreements in the implementation of their mandate, including through the provision of technical assistance and logistical support to those bodies;

iv.   To facilitate the preparation and conduct of the Darfur-Darfur Dialogue and Consultation,, as stipulated in the Darfur Peace Agreement;

v.   To assist in the preparations for the conduct of the referendums provided for in the Darfur Peace Agreement;

vi.   To ensure the complementary implementation of all peace agreements in the Sudan, particularly with regard to the national provisions of those agreements, and compliance with the Interim National Constitution;

vii. To liaise with UNMIS, the African Union Liaison Office for the implementation of the Comprehensive Peace Agreement and other stakeholders to ensure complementary implementation of the mandates of UNMIS, the

African Union Liaison Office for the implementation of the Comprehensive Peace Agreement and the hybrid operation in Darfur;

Security:

i. To promote the re-establishment of confidence, deter violence and assist in monitoring and verifying the implementation of the redeployment and disengagement provisions of the Darfur Peace Agreement, including by actively providing security and robust patrolling of redeployment and buffer zones, by monitoring the withdrawal of long-range weapons, and by deploying hybrid police, including formed police units, in areas where internally displaced persons are concentrated, in the demilitarized and buffer zones, along key routes of migration and in other vital areas, including as provided for in the Darfur Peace Agreement;

ii. To monitor, investigate, report and assist the parties in resolving violations of the Darfur Peace Agreement and subsequent complementary agreements through the Ceasefire Commission and the Joint Commission;

iii. To monitor, verify and promote efforts to disarm the Janjaweed and other militias;

iv. To coordinate non-combat logistical support for the movements;

v. To assist in the establishment of the disarmament, demobilization and reintegration programme called for in the Darfur Peace Agreement;

vi. To contribute to the creation of the necessary security conditions for the provision of humanitarian assistance and to facilitate the voluntary and sustainable return of refugees and internally displaced persons to their homes;

vii. In the areas of deployment of its forces and within its capabilities, to protect the hybrid operation's personnel, facilities, installations and equipment, to ensure the security and freedom of movement of United Nations-African Union personnel, humanitarian workers and Assessment and Evaluation Commission personnel, to prevent disruption of the implementation of the Darfur Peace Agreement by armed groups and, without prejudice to the responsibility of the Government of the Sudan, to protect civilians under imminent threat of physical violence and prevent attacks and threats against civilians;

viii. To monitor through proactive patrolling the parties' policing activities in camps for internally displaced persons, demilitarized and buffer zones and areas of control;

ix. To support, in coordination with the parties, as outlined in the Darfur Peace Agreement, the establishment and training of community police in camps for internally displaced persons, to support capacity-building of the Government of the Sudan police in Darfur, in accordance with international standards of human rights and accountability, and to support the institutional development of the police of the movements;

x. To support the efforts of the Government of the Sudan and of the police of the movements to maintain public order and build the capacity of Sudanese law enforcement in this regard through specialized training and joint operations;

xi. To provide technical mine-action advice and coordination and demining capacity to support the Darfur Peace Agreement;

Rule of law, governance, and human rights:

i. To assist in the implementation of the provisions of the Darfur Peace Agreement and any subsequent agreements relating to human rights and the rule of law and to contribute to the creation of an environment conducive to respect for human rights and the rule of law, in which all are ensured effective protection;

ii. To assist all stakeholders and local government authorities, in particular in their efforts to transfer resources in an equitable manner from the federal Government to the Darfur states, and to implement reconstruction plans and existing and subsequent agreements on land use and compensation issues;

iii. To support the parties to the Darfur Peace Agreement in restructuring and building the capacity of the police service in Darfur, including through monitoring, training, mentoring, co-location and joint patrols;

iv. To assist in promoting the rule of law, including through institution-building, and strengthening local capacities to combat impunity;

v. To ensure an adequate human rights and gender presence capacity, and expertise in Darfur in order to contribute to efforts to protect and promote human rights in Darfur, with particular attention to vulnerable groups;

vi. To assist in harnessing the capacity of women to participate in the peace process, including through political representation, economic empowerment and protection from gender-based violence;

vii. To support the implementation of provisions included in the Darfur Peace Agreement and any subsequent agreements relating to upholding the rights of children;

Humanitarian assistance:

i. To facilitate the effective provision of humanitarian assistance and full access to people in need.

Appendix 2   HTML source code of SIRS

```
1    <!-- HTML webpage
2         Incidence Security Reporting System (SIRS)
3         Client application to administer the security incidents database
4         Arne Schumacher, U1455                                    -->
5    <html>
6        <head>
7            <title>SIRS</title>
8            <!-- base layers-->
9            <script src=
     "http://maps.google.com/maps?file=api&amp;v=2&amp;key=ABQIAAAA9XNhd8q0UdwNC7YSO4YZgh
     SPUCi5aRYVveCcVYxzezM4iaj_gxQ9t-UajFL70jfcpquH5l1IJ-Zyyw"></script>
10           <script src=
     "http://dev.virtualearth.net/mapcontrol/mapcontrol.ashx?v=6.2&mkt=en-us"></script>
11           <script src=
     "http://api.maps.yahoo.com/ajaxymap?v=3.0&appid=euzuro-openlayers"></script>
12
13           <!-- layout (*.css) and extensions (*.js) -->
14           <link rel="stylesheet" type="text/css" href=
     "./ext-3.3.0/resources/css/ext-all.css" />
15           <link rel="stylesheet" type="text/css" href=
     "./ext-3.3.0/examples/shared/examples.css" />
16           <script type="text/javascript" src="./ext-3.3.0/adapter/ext/ext-base.js"
     ></script>
17           <script type="text/javascript" src="./ext-3.3.0/ext-all-debug.js"></script>
18
19           <script type="text/javascript" src="./openlayers/lib/OpenLayers.js"
     ></script>
20
21           <script type="text/javascript" src="./GeoExt/lib/GeoExt.js"></script>
22           <script type="text/javascript" src=
     "./GeoExt/lib/GeoExt/data/FeatureEditorGrid.js"></script>
23
24           <!-- calling external JavaScript file -- Key file for all dynamic
     components of SIRS-->
25           <script type="text/javascript" src="master_thesis.js"></script>
26
27           <!-- All exceptions from the above stylesheets (*.css) are referenced here
     -->
28           <link rel="stylesheet" href="./openlayers/theme/default/style.css" type=
     "text/css" />
29           <style type="text/css">
30           div.olControlMousePosition {
31           color: #ffffff;
32           font-size: bigger;
33           font-weight: bold;
34           }
35
36           .indented
37           {
38           padding-left: 15pt;
39           padding-right: 15pt;
40           }
41           </style>
42
43       </head>
44       <body>
```

```
45    <table width="1125" height="750" border="2">
46      <!-- Header -->
47      <tr>
48        <td height="104" colspan="2"><img src="./openlayers/img/SIRS_Header.png" width=
      "1120" height="100" alt="Header" /></td>
49      </tr>
50      <!-- SIRS -->
51      <tr>
52        <td colspan="2">
53        <div id="panel"</div>
54        <div id="results"></div>
55        </td>
56      </tr>
57      <!-- Footer -->
58      <tr>
59        <td width="650"><B><h2><font size=3 class="indented">Instructions</font size
      ></a></h2>
60        <font size=2>
61          <p align=justify class="indented">&bull To <i>retrieve feature information
      </i>, use the &quot;Feature Info&quot; button and select a feature in the map.</p>
62          <p align=justify class="indented">&bull To <i>add an incident</i>, use the
      &quot;Add Incident&quot; button. Choose the location in the map and fill out the
      attribute form as comprehensive as posssible. Press the &quot;Save&quot; button
      afterwards.</p>
63          <p align=justify class="indented">&bull To <i>edit an incident</i>, use the
      &quot;Edit Incident&quot; button. Select a feature in the map and change its
      attributes. To complete, press &quot;Save&quot;.</p>
64          <p align=justify class="indented">&bull To <i>delete an incident</i>, use
      the &quot;Edit Incident&quot; button, select a feature in the map and confirm by
      pressing the &quot;Delete&quot; button. <br />
65        </p></font size></B></td>
66
67        <td width="475"><h2><B><font size=3 class="indented">Disclaimer</font size></h2>
68        <font size=2>
69
70          <p align=justify class="indented" >All information in this webpage has no
      offical approval by the United Nations or its subsidiary organisations. The
      information and data contained in this application are to substantiate the
      technological infrastructure and do not claim any validity or express the opinion
      of the UN.</p>
71          <p align=justify class="indented">The information is solely a demonstration
      application to edit security incidents for the accomplishement of the master
      thesis by:</p>
72          <p align=justify class="indented">Arne Schumacher, UNIGIS year 2009, U1455
      </p><p></p>
73        </font size></B></td>
74      </tr>
75    </table>
76    </body>
77    </html>
```

Appendix 3   JavaScript source code of SIRS

```
1    /**
2     * JavaScript functionality
3     *
4     * Webbased Incidence Security Reporting System (SIRS)
5     * Client application to administer the security incidents database
6     *
7     * Arne Schumacher, U1455
8     */
9
10   var map;
11   var sphericalMercator = new OpenLayers.Projection("EPSG:900913");
12   var geographicProjection = new OpenLayers.Projection("EPSG:4326");
13   var pureCoverage = false;
14   var mapPanel, editingContainer, selectFeature, showAttribute;
15
16   //WFS-T
17   var protocol = new OpenLayers.Protocol.WFS({
18           url:  "http://localhost:8080/geoserver/wfs",
19           outputFormat: "GML2",
20           featureType: "incidence_occurrences",
21           featurePrefix: "MasterThesis",
22           geometryName:"the_geom",
23           version:"1.1.0",
24           srsName:"EPSG:4326"
25           })
26
27   function closeEditing() {
28       // avoid reentrance
29       if(!arguments.callee._in) {
30           arguments.callee._in = true;
31           editingContainer.removeAll(true);
32           selectFeature.unselectAll();
33           delete arguments.callee._in;
34       }
35       }
36
37     // style WFS-T
38     function createVectorLayer() {
39
40       var styleDefault = Ext.applyIf({
41           graphicName: "${symbol}",
42           pointRadius: "${size}"
43       }, OpenLayers.Feature.Vector.style["default"]);
44
45       var styleSelect = Ext.applyIf({
46           graphicName: "${symbol}",
47           pointRadius: "${size}"
48       }, OpenLayers.Feature.Vector.style["select"]);
49
50       // retrieve WFS-T
51       return new OpenLayers.Layer.Vector("Edit Incidents", {
52           strategies: [new OpenLayers.Strategy.Fixed()],
53           Visibility: true,
54           projection: geographicProjection, // = new
     OpenLayers.Projection("EPSG:4326"),
55           protocol: protocol,
```

90

```
56              eventListeners: {
57               beforefeatureadded: function(e) {
58                closeEditing();
59                selectFeature.select(e.feature);
60               },
61               beforefeatureselected: function(e) {
62                addEditorGrid(e.feature);
63               },
64               featureunselected: function(e) {
65                closeEditing();
66
67              }
68             }
69           });
70         }
71
72  // get and create attribute form
73  function addEditorGrid(feature) {
74
75     var store = new GeoExt.data.AttributeStore({
76         url:
    "http://localhost:8080/geoserver/wfs/DescribeFeatureType?version=1.1.0&typename=Mast
    erThesis:incidence_occurrences&",
77         feature: feature,
78         fields: ["name", "type", "restriction", "label"],
79         data: [
80         {
81             name: "incident",
82             label: "Incident",
83             type: "string"
84         },
85         {
86             name: "victim",
87             label: "Victim",
88             type: "string"
89         },
90         {
91             name: "offender",
92             label: "Offender",
93             type: "string"
94         },
95         {
96             name: "org_type",
97             label: "Organisation Type",
98             type: "string"
99         },
100        {
101            name: "date",
102            label: "Date",
103            type: "date"
104        },
105        {
106            name: "time",
107            label: "Time",
108            type: "string"
109        },
```

91

```
110             {
111                 name: "location",
112                 label: "Location",
113                 type: "string"
114             },
115             {
116                 name: "ruralconcl",
117                 label: "Rural Council",
118                 type: "string"
119             },
120             {
121                 name: "locality",
122                 label: "Locality",
123                 type: "string"
124             },
125             {
126                 name: "state",
127                 label: "State",
128                 type: "string"
129             },
130             {
131                 name: "source",
132                 label: "Source",
133                 type: "string"
134             },
135             {
136                 name: "remarks",
137                 label: "Remarks",
138                 type: "string"
139             }
140             ]
141         });
142
143         // diplay attribute form in container
144         var editorGrid = new GeoExt.ux.FeatureEditorGrid({
145             nameField: "label",
146             store: store,
147             forceValidation: true,
148             allowSave: true,
149             allowCancel: true,
150             allowDelete: true,
151              listeners: {
152                 done: function(panel, e) {
153                     closeEditing();
154                     console.log(e.feature.fid)
155                     //update insert code
156                     //convert Google mouseclick coordinates to essential geographic
    coordinates for database
157                     e.feature.geometry.transform(sphericalMercator,geographicProjection
    );
158                     if (e.feature.fid == null && e.text=="Save"){
159                     e.feature.state = OpenLayers.State.INSERT;
160                     //confirm insert via message box
161                     Ext.Msg.show({
162                     title:'You have successully added the incident',
163                     buttons: Ext.Msg.OK,
```

```
164                         });
165                         }
166                         else if (e.feature.fid != null && e.text=="Save") {
167                         e.feature.state = OpenLayers.State.UPDATE
168                         }
169                         else if (e.text=="Delete") {
170                         e.feature.state = OpenLayers.State.DELETE
171                         }
172                         else {
173                         }
174                         protocol.commit([e.feature])
175                         var feature = e.feature, modified = e.modified;
176                         if(feature.state != null) {
177                             setTimeout(function() {
178                                 if(feature.state === OpenLayers.State.DELETE) {
179                                     feature.layer.destroyFeatures([feature]);
180                                 } else {
181                                     feature.state = null;
182                                 }
183                             }, 1);
184                         }
185                     },
186
187                 cancel: function(panel, e) {
188                     var feature = e.feature, modified = e.modified;
189                     panel.cancel();
190                     closeEditing();
191                     if(feature.state === OpenLayers.State.INSERT) {
192                         feature.layer.destroyFeatures([feature]);
193                     }
194                     // call cancel to return false here
195                     return false;
196                 }
197         }
198     });
199
200     editingContainer.add(editorGrid);
201     editingContainer.doLayout();
202
203     feature.layer.drawFeature(feature, "select");
204 }
205
206 Ext.onReady(function() {
207
208         format = 'image/jpeg';
209                 if(pureCoverage) {
210                     format = "image/jpeg";
211                 }
212
213     var options = {
214                 // map parameters
215                 projection: sphericalMercator, // = new
    OpenLayers.Projection("EPSG:900913"),
216                 displayProjection: geographicProjection, // = new
    OpenLayers.Projection("EPSG:4326"),
217                 units: "m",
```

```
218                     maxResolution: 78271.51695,
219                     maxExtent: new OpenLayers.Bounds(2295332.188819, 1160395.193045,
        3464512.97326, 1784121.343741    )
220                 };
221         map = new OpenLayers.Map('map', options);
222
223         //add controls
224         map.addControl(new OpenLayers.Control.PanZoomBar());
225         map.addControl(new OpenLayers.Control.NavToolbar());
226         map.addControl(new OpenLayers.Control.LayerSwitcher({'ascending':false}));
227         map.addControl(new OpenLayers.Control.MousePosition({numDigits:4}));
228         map.addControl(new OpenLayers.Control.OverviewMap());
229         map.addControl(new OpenLayers.Control.KeyboardDefaults());
230
231         // avoid pink tiles
232             OpenLayers.IMAGE_RELOAD_ATTEMPTS = 3;
233             OpenLayers.Util.onImageLoadErrorColor = "transparent";
234
235         // initialise base layers
236                 var gsat = new OpenLayers.Layer.Google(
237                     "Google Hybrid",
238                     {type: G_HYBRID_MAP, sphericalMercator: true}
239                 );
240
241                 var gphy = new OpenLayers.Layer.Google( "Google Terrain",
242                     {type: G_PHYSICAL_MAP, 'sphericalMercator': true
243                 });
244
245                 var yahoosat = new OpenLayers.Layer.Yahoo("Yahoo Maps", {
246                      sphericalMercator: true
247                 });
248
249                 var olwms = new OpenLayers.Layer.WMS( "OpenLayers WMS",
250                         "http://labs.metacarta.com/wms/vmap0", {layers: 'basic'} );
251
252         // initialise non-base layers (overlays)
253
254         var incidents = new OpenLayers.Layer.WMS(
255                     "Incident occurrences",
256                     "http://localhost:8080/geoserver/wms?",
257                     {
258                         layers: 'MasterThesis:incidence_occurrences',
259                         styles: '',
260                         srs: 'EPSG:900913',
261                         format: 'image/png',
262                         transparent: true
263                     },
264                     {
265                         singleTile: true, 'opacity': 0.9, 'isBaseLayer': false,
        'wrapDateLine': true
266                     }
267                 );
268
269                 var camps_poly = new OpenLayers.Layer.WMS(
270                     "UNAMID Camps Polygon",
```

94

```
271                     "http://localhost:8080/geoserver/wms?",
272                     {
273                         layers: 'MasterThesis:camps_poly',
274                         styles: '',
275                         srs: 'EPSG:4326',
276                         format: 'image/png',
277                         transparent: true
278                     },
279                     {
280                         singleTile: true, 'opacity': 0.9, 'isBaseLayer': false,
     'wrapDateLine': true
281                     }
282                 );
283
284             var unamid_camps_point = new OpenLayers.Layer.WMS(
285                     "UNAMID Camps Point",
286                     "http://localhost:8080/geoserver/wms?",
287                     {
288                         layers: 'MasterThesis:unamid_camps_point',
289                         styles: '',
290                         srs: 'EPSG:4326',
291                         format: 'image/png',
292                         transparent: true
293                     },
294                     {
295                         singleTile: true, 'opacity': 0.9, 'isBaseLayer': false,
     'wrapDateLine': true
296                     }
297                 );
298
299             var communal_police_center = new OpenLayers.Layer.WMS(
300                     "Communal Police Center",
301                     "http://localhost:8080/geoserver/wms?",
302                     {
303                         layers: 'MasterThesis:communal_police_center',
304                         styles: '',
305                         srs: 'EPSG:4326',
306                         format: 'image/png',
307                         transparent: true
308                     },
309                     {
310                         singleTile: true, 'opacity': 0.9, 'isBaseLayer': false,
     'wrapDateLine': true
311                     }
312                 );
313
314             var battalion_boundary = new OpenLayers.Layer.WMS(
315                     "UNAMID Battalion Boundary",
316                     "http://localhost:8080/geoserver/wms?",
317                     {
318                         layers: 'MasterThesis:battalion_boundary',
319                         styles: '',
320                         srs: 'EPSG:4326',
321                         format: 'image/png',
322                         transparent: true
323                     },
```

```
324                    {
325                        singleTile: true, 'opacity': 0.9, 'isBaseLayer': false,
     'wrapDateLine': true
326                    }
327                );
328
329        var vecLayer = createVectorLayer();
330
331        vecLayer.setOpacity(0.3);
332
333        map.addLayers([gsat, gphy, yahoosat, olwms, vecLayer, incidents, camps_poly,
     unamid_camps_point, communal_police_center, battalion_boundary]);
334
335        var drawFeature = new OpenLayers.Control.DrawFeature(
336            vecLayer, OpenLayers.Handler.Point, {
337                eventListeners: {
338                    deactivate: closeEditing
339                }
340        });
341
342        selectFeature = new OpenLayers.Control.SelectFeature(vecLayer, {
343            eventListeners: {
344                deactivate: closeEditing
345            }
346        });
347
348        var WMSGetFeatureInfo = new OpenLayers.Control.WMSGetFeatureInfo(
349        {url:   "http://localhost:8080/geoserver/wms?",
350        infoFormat: 'text/html',
351        eventListeners: {
352            getfeatureinfo: event
353            }
354        }
355        );
356
357        // display WMSGetFeatureInfo
358        function event(request) {
359            var results = request.request.responseText;
360            //alert(results);
361            document.getElementById('results').innerHTML = results;
362            }
363
364        var tools = [
365            "->",
366            new GeoExt.Action({
367                control: WMSGetFeatureInfo,
368                map: map,
369                toggleGroup: "edit",
370                pressed: true,
371                allowDepress: false,
372                text: "Feature Info",
373                icon: './openlayers/img/Info.png',
374                handler: function (){Ext.Msg.alert('Click','Select a feature to get
     info');
375                },
376            }),
```

96

```
377            new GeoExt.Action({
378                control: drawFeature,
379                map: map,
380                toggleGroup: "edit",
381                pressed: false,
382                allowDepress: false,
383                text: "Add incident",
384                icon: './openlayers/img/Add_Incident.png',
385            }),
386            new GeoExt.Action({
387                control: selectFeature,
388                map: map,
389                toggleGroup: "edit",
390                pressed: false,
391                allowDepress: false,
392                text: "Edit incident",
393                icon: './openlayers/img/edit_incident.png'
394            })
395        ];
396
397        mapPanel = new GeoExt.MapPanel({
398            title: "Incidence Map",
399            region: "center",
400            height: 500,
401            width: 770,
402            map: map,
403            center: new OpenLayers.LonLat(25,13),
404            zoom: 6,
405            tbar: tools
406        });
407
408        editingContainer = new Ext.Panel({
409            title: "Edit Incidents",
410            region: "east",
411            layout: "fit",
412            width: 230,
413            collapsible: true
414        });
415
416        //prepare layers to be displayed in legendpanel
417        var store = new GeoExt.data.LayerStore({
418        layers: [battalion_boundary, camps_poly, communal_police_center,
        unamid_camps_point, incidents]
419        });
420
421        //Get Legend by using WMSGetLegendGraphic
422        //i.e.
        http://localhost:8080/geoserver/wms?REQUEST=GetLegendGraphic&VERSION=1.0.0&FORMAT=im
        age/png&WIDTH=20&HEIGHT=20&LAYER=MasterThesis:incidence_occurrences
423        legendinformation = new GeoExt.LegendPanel({
424            title: "Legend",
425            region: "west",
426            layout: "fit",
427            height: 300,
428            width: 200,
429            layerStore: store,
```

```
430            autoScroll: true,
431            collapsible: true,
432            bodyStyle: 'padding:5px',
433        });
434
435        showAttribute = new Ext.Panel({
436            title: "Feature Selection",
437            region: "south",
438            //layout: "fit",
439            height: 220,
440            //width: 600,
441            contentEl: 'results',
442            autoScroll: true,
443            collapsible: true
444        });
445
446        new Ext.Panel({
447            renderTo: "panel",
448            layout: "border",
449            height: 900,
450            width: 1120,
451            items: [mapPanel, editingContainer, showAttribute, legendinformation]
452        });
453    });
```

Appendix 4   Styled Layer Descriptor for the symbology of the incidents dataset

```xml
1   <?xml version="1.0" encoding="ISO-8859-1"?>
2   <StyledLayerDescriptor version="1.0.0"
3       xsi:schemaLocation="http://www.opengis.net/sld StyledLayerDescriptor.xsd"
4       xmlns="http://www.opengis.net/sld"
5       xmlns:ogc="http://www.opengis.net/ogc"
6       xmlns:xlink="http://www.w3.org/1999/xlink"
7       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
8     <NamedLayer>
9       <Name>Symbology for layer incidence_occurrences</Name>
10      <UserStyle>
11        <Title>Symbology attribute distinction</Title>
12        <FeatureTypeStyle>
13          <Rule>
14            <Name>Abduction</Name>
15            <ogc:Filter>
16              <ogc:PropertyIsEqualTo>
17                <ogc:PropertyName>INCIDENT</ogc:PropertyName>
18                <ogc:Literal>Abduction</ogc:Literal>
19              </ogc:PropertyIsEqualTo>
20            </ogc:Filter>
21            <PointSymbolizer>
22              <Graphic>
23                <ExternalGraphic>
24                  <OnlineResource
25                    xlink:type="simple"
26                    xlink:href=
    "http://localhost:8080/geoserver/styles/images_incidents/abduction.png" />
27                  <Format>image/png</Format>
28                </ExternalGraphic>
29                <Size>22</Size>
30              </Graphic>
31            </PointSymbolizer>
32          </Rule>
33        </FeatureTypeStyle>
34        <FeatureTypeStyle>
35          <Rule>
36            <Name>Carjacking</Name>
37            <ogc:Filter>
38              <ogc:PropertyIsEqualTo>
39                <ogc:PropertyName>INCIDENT</ogc:PropertyName>
40                <ogc:Literal>Carjacking</ogc:Literal>
41              </ogc:PropertyIsEqualTo>
42            </ogc:Filter>
43            <PointSymbolizer>
44              <Graphic>
45                <ExternalGraphic>
46                  <OnlineResource
47                    xlink:type="simple"
48                    xlink:href=
    "http://localhost:8080/geoserver/styles/images_incidents/carjacking.png" />
49                  <Format>image/png</Format>
50                </ExternalGraphic>
51                <Size>22</Size>
52              </Graphic>
53            </PointSymbolizer>
54          </Rule>
```

```
55            </FeatureTypeStyle>
56            <FeatureTypeStyle>
57              <Rule>
58                <Name>Armed Clash</Name>
59                <ogc:Filter>
60                  <ogc:PropertyIsEqualTo>
61                    <ogc:PropertyName>incident</ogc:PropertyName>
62                    <ogc:Literal>Armed Clash</ogc:Literal>
63                  </ogc:PropertyIsEqualTo>
64                </ogc:Filter>
65                <PointSymbolizer>
66                  <Graphic>
67                    <ExternalGraphic>
68                      <OnlineResource
69                        xlink:type="simple"
70                        xlink:href=
     "http://localhost:8080/geoserver/styles/images/armed_clash.png" />
71                      <Format>image/png</Format>
72                    </ExternalGraphic>
73                    <Size>22</Size>
74                  </Graphic>
75                </PointSymbolizer>
76              </Rule>
77            </FeatureTypeStyle>
78            <FeatureTypeStyle>
79              <Rule>
80                <Name>Arrest</Name>
81                <ogc:Filter>
82                  <ogc:PropertyIsEqualTo>
83                    <ogc:PropertyName>incident</ogc:PropertyName>
84                    <ogc:Literal>Arrest</ogc:Literal>
85                  </ogc:PropertyIsEqualTo>
86                </ogc:Filter>
87                <PointSymbolizer>
88                  <Graphic>
89                    <ExternalGraphic>
90                      <OnlineResource
91                        xlink:type="simple"
92                        xlink:href=
     "http://localhost:8080/geoserver/styles/images/arrest.png" />
93                      <Format>image/png</Format>
94                    </ExternalGraphic>
95                    <Size>22</Size>
96                  </Graphic>
97                </PointSymbolizer>
98              </Rule>
99            </FeatureTypeStyle>
100           <FeatureTypeStyle>
101             <Rule>
102               <Name>Denial of access</Name>
103               <ogc:Filter>
104                 <ogc:PropertyIsEqualTo>
105                   <ogc:PropertyName>incident</ogc:PropertyName>
106                   <ogc:Literal>Denial of Access</ogc:Literal>
107                 </ogc:PropertyIsEqualTo>
108               </ogc:Filter>
```

```
109              <PointSymbolizer>
110                <Graphic>
111                  <ExternalGraphic>
112                    <OnlineResource
113                      xlink:type="simple"
114                      xlink:href=
     "http://localhost:8080/geoserver/styles/images/denial_of_access.png" />
115                    <Format>image/png</Format>
116                  </ExternalGraphic>
117                  <Size>22</Size>
118                </Graphic>
119              </PointSymbolizer>
120            </Rule>
121          </FeatureTypeStyle>
122          <FeatureTypeStyle>
123            <Rule>
124              <Name>Intimidation</Name>
125              <ogc:Filter>
126                <ogc:PropertyIsEqualTo>
127                  <ogc:PropertyName>incident</ogc:PropertyName>
128                  <ogc:Literal>Intimidation</ogc:Literal>
129                </ogc:PropertyIsEqualTo>
130              </ogc:Filter>
131              <PointSymbolizer>
132                <Graphic>
133                  <ExternalGraphic>
134                    <OnlineResource
135                      xlink:type="simple"
136                      xlink:href=
     "http://localhost:8080/geoserver/styles/images/intimidation.png" />
137                    <Format>image/png</Format>
138                  </ExternalGraphic>
139                  <Size>22</Size>
140                </Graphic>
141              </PointSymbolizer>
142            </Rule>
143          </FeatureTypeStyle>
144        <FeatureTypeStyle>
145            <Rule>
146              <Name>Traffic Accident</Name>
147              <ogc:Filter>
148                <ogc:PropertyIsEqualTo>
149                  <ogc:PropertyName>incident</ogc:PropertyName>
150                  <ogc:Literal>Traffic Accident</ogc:Literal>
151                </ogc:PropertyIsEqualTo>
152              </ogc:Filter>
153              <PointSymbolizer>
154                <Graphic>
155                  <ExternalGraphic>
156                    <OnlineResource
157                      xlink:type="simple"
158                      xlink:href=
     "http://localhost:8080/geoserver/styles/images/traffic_accident.png" />
159                    <Format>image/png</Format>
160                  </ExternalGraphic>
161                  <Size>22</Size>
```

```
162                 </Graphic>
163             </PointSymbolizer>
164          </Rule>
165       </FeatureTypeStyle>
166    <FeatureTypeStyle>
167       <Rule>
168          <Name>Medical Evacuation</Name>
169          <ogc:Filter>
170            <ogc:PropertyIsEqualTo>
171              <ogc:PropertyName>incident</ogc:PropertyName>
172              <ogc:Literal>Medical Evacuation</ogc:Literal>
173            </ogc:PropertyIsEqualTo>
174          </ogc:Filter>
175          <PointSymbolizer>
176            <Graphic>
177              <ExternalGraphic>
178                <OnlineResource
179                  xlink:type="simple"
180                  xlink:href=
   "http://localhost:8080/geoserver/styles/images/medical_evacuation.png" />
181                <Format>image/png</Format>
182              </ExternalGraphic>
183              <Size>22</Size>
184            </Graphic>
185          </PointSymbolizer>
186       </Rule>
187       </FeatureTypeStyle>
188    <FeatureTypeStyle>
189       <Rule>
190          <Name>Rape</Name>
191          <ogc:Filter>
192            <ogc:PropertyIsEqualTo>
193              <ogc:PropertyName>incident</ogc:PropertyName>
194              <ogc:Literal>Rape</ogc:Literal>
195            </ogc:PropertyIsEqualTo>
196          </ogc:Filter>
197          <PointSymbolizer>
198            <Graphic>
199              <ExternalGraphic>
200                <OnlineResource
201                  xlink:type="simple"
202                  xlink:href=
   "http://localhost:8080/geoserver/styles/images/rape.png" />
203                <Format>image/png</Format>
204              </ExternalGraphic>
205              <Size>22</Size>
206            </Graphic>
207          </PointSymbolizer>
208       </Rule>
209       </FeatureTypeStyle>
210    <FeatureTypeStyle>
211       <Rule>
212          <Name>Murder</Name>
213          <ogc:Filter>
214            <ogc:PropertyIsEqualTo>
215              <ogc:PropertyName>incident</ogc:PropertyName>
```

```
216                    <ogc:Literal>Murder</ogc:Literal>
217                </ogc:PropertyIsEqualTo>
218              </ogc:Filter>
219              <PointSymbolizer>
220                <Graphic>
221                  <ExternalGraphic>
222                    <OnlineResource
223                      xlink:type="simple"
224                      xlink:href=
       "http://localhost:8080/geoserver/styles/images/murder.png" />
225                    <Format>image/png</Format>
226                  </ExternalGraphic>
227                  <Size>22</Size>
228                </Graphic>
229              </PointSymbolizer>
230            </Rule>
231          </FeatureTypeStyle>
232        <FeatureTypeStyle>
233            <Rule>
234              <Name>Theft</Name>
235              <ogc:Filter>
236                <ogc:PropertyIsEqualTo>
237                  <ogc:PropertyName>incident</ogc:PropertyName>
238                  <ogc:Literal>Theft</ogc:Literal>
239                </ogc:PropertyIsEqualTo>
240              </ogc:Filter>
241              <PointSymbolizer>
242                <Graphic>
243                  <ExternalGraphic>
244                    <OnlineResource
245                      xlink:type="simple"
246                      xlink:href=
       "http://localhost:8080/geoserver/styles/images/theft.png" />
247                    <Format>image/png</Format>
248                  </ExternalGraphic>
249                  <Size>22</Size>
250                </Graphic>
251              </PointSymbolizer>
252            </Rule>
253          </FeatureTypeStyle>
254        <FeatureTypeStyle>
255            <Rule>
256              <Name>Damage to Property</Name>
257              <ogc:Filter>
258                <ogc:PropertyIsEqualTo>
259                  <ogc:PropertyName>incident</ogc:PropertyName>
260                  <ogc:Literal>Damage to Property</ogc:Literal>
261                </ogc:PropertyIsEqualTo>
262              </ogc:Filter>
263              <PointSymbolizer>
264                <Graphic>
265                  <ExternalGraphic>
266                    <OnlineResource
267                      xlink:type="simple"
268                      xlink:href=
       "http://localhost:8080/geoserver/styles/images/damage_to_property_.png" />
```

```
269                          <Format>image/png</Format>
270                      </ExternalGraphic>
271                      <Size>22</Size>
272                  </Graphic>
273              </PointSymbolizer>
274          </Rule>
275      </FeatureTypeStyle>
276      <FeatureTypeStyle>
277          <Rule>
278              <Name>Banditry</Name>
279              <ogc:Filter>
280                  <ogc:PropertyIsEqualTo>
281                      <ogc:PropertyName>incident</ogc:PropertyName>
282                      <ogc:Literal>Banditry</ogc:Literal>
283                  </ogc:PropertyIsEqualTo>
284              </ogc:Filter>
285              <PointSymbolizer>
286                  <Graphic>
287                      <ExternalGraphic>
288                          <OnlineResource
289                              xlink:type="simple"
290                              xlink:href=
    "http://localhost:8080/geoserver/styles/images/banditry.png" />
291                          <Format>image/png</Format>
292                      </ExternalGraphic>
293                      <Size>22</Size>
294                  </Graphic>
295              </PointSymbolizer>
296          </Rule>
297      </FeatureTypeStyle>
298      <FeatureTypeStyle>
299          <Rule>
300              <Name>Others</Name>
301              <ogc:Filter>
302                  <ogc:PropertyIsEqualTo>
303                      <ogc:PropertyName>incident</ogc:PropertyName>
304                      <ogc:Literal>Others</ogc:Literal>
305                  </ogc:PropertyIsEqualTo>
306              </ogc:Filter>
307              <PointSymbolizer>
308                  <Graphic>
309                      <ExternalGraphic>
310                          <OnlineResource
311                              xlink:type="simple"
312                              xlink:href=
    "http://localhost:8080/geoserver/styles/images/others.png" />
313                          <Format>image/png</Format>
314                      </ExternalGraphic>
315                      <Size>22</Size>
316                  </Graphic>
317              </PointSymbolizer>
318          </Rule>
319      </FeatureTypeStyle>
320      </UserStyle>
321    </NamedLayer>
322  </StyledLayerDescriptor>
```

Appendix 5   GetCapabilites document for SIRS

```xml
<?xml version="1.0" encoding="UTF-8" ?>
<WFS_Capabilities version="1.0.0" xmlns="http://www.opengis.net/wfs"
  xmlns:it.geosolutions="http://www.geo-solutions.it"
  xmlns:cite="http://www.opengeospatial.net/cite" xmlns:tiger="http://www.census.gov"
  xmlns:sde="http://geoserver.sf.net" xmlns:topp="http://www.openplans.org/topp"
  xmlns:MasterThesis="http://localhost:8080/geoserver/"
  xmlns:sf="http://www.openplans.org/spearfish"
  xmlns:Openlayers_examples="http://localhost:8080/geoserver/www/openlayers/examples"
  xmlns:nurc="http://www.nurc.nato.int" xmlns:ogc="http://www.opengis.net/ogc"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.opengis.net/wfs
  http://localhost:8080/geoserver/schemas/wfs/1.0.0/WFS-capabilities.xsd">
  <Service>
    <Name>WFS</Name>
    <Title>GeoServer Web Feature Service</Title>
    <Abstract>This is the reference implementation of WFS 1.0.0 and WFS 1.1.0, supports
      all WFS operations including Transaction.</Abstract>
    <Keywords>WFS, WMS, GEOSERVER</Keywords>
    <OnlineResource>http://localhost:8080/geoserver/wfs</OnlineResource>
    <Fees>NONE</Fees>
    <AccessConstraints>UNAMID Intranet</AccessConstraints>
  </Service>
  <Capability>
    <Request>
      <GetCapabilities>
        <DCPType>
          <HTTP>
            <Get onlineResource="http://localhost:8080/geoserver/wfs?
              request=GetCapabilities" />
          </HTTP>
        </DCPType>
        <DCPType>
          <HTTP>
            <Post onlineResource="http://localhost:8080/geoserver/wfs" />
          </HTTP>
        </DCPType>
      </GetCapabilities>
      <DescribeFeatureType>
        <SchemaDescriptionLanguage>
          <XMLSCHEMA />
        </SchemaDescriptionLanguage>
        <DCPType>
          <HTTP>
            <Get onlineResource="http://localhost:8080/geoserver/wfs?
              request=DescribeFeatureType" />
          </HTTP>
        </DCPType>
        <DCPType>
          <HTTP>
            <Post onlineResource="http://localhost:8080/geoserver/wfs" />
          </HTTP>
        </DCPType>
      </DescribeFeatureType>
      <GetFeature>
        <ResultFormat>
          <GML2 />
          <GML3 />
          <SHAPE-ZIP />
          <GEOJSON />
```

```xml
            <CSV />
          </ResultFormat>
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          - <HTTP>
              <Get onlineResource="http://localhost:8080/geoserver/wfs?
                request=GetFeature" />
            </HTTP>
          </DCPType>
        - <DCPType>
          - <HTTP>
              <Post onlineResource="http://localhost:8080/geoserver/wfs" />
            </HTTP>
          </DCPType>
        </GetFeature>
      - <Transaction>
        - <DCPType>
          - <HTTP>
              <Get onlineResource="http://localhost:8080/geoserver/wfs?
                request=Transaction" />
            </HTTP>
          </DCPType>
        - <DCPType>
          - <HTTP>
              <Post onlineResource="http://localhost:8080/geoserver/wfs" />
            </HTTP>
          </DCPType>
        </Transaction>
      - <LockFeature>
        - <DCPType>
          - <HTTP>
              <Get onlineResource="http://localhost:8080/geoserver/wfs?
                request=LockFeature" />
            </HTTP>
          </DCPType>
        - <DCPType>
          - <HTTP>
              <Post onlineResource="http://localhost:8080/geoserver/wfs" />
            </HTTP>
          </DCPType>
        </LockFeature>
      - <GetFeatureWithLock>
        - <ResultFormat>
            <GML2 />
          </ResultFormat>
        - <DCPType>
          - <HTTP>
              <Get onlineResource="http://localhost:8080/geoserver/wfs?
                request=GetFeatureWithLock" />
            </HTTP>
          </DCPType>
        - <DCPType>
          - <HTTP>
              <Post onlineResource="http://localhost:8080/geoserver/wfs" />
            </HTTP>
          </DCPType>
        </GetFeatureWithLock>
      </Request>
  </Capability>
```

```xml
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  - <Operations>
      <Query />
      <Insert />
      <Update />
      <Delete />
      <Lock />
    </Operations>
  - <FeatureType>
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      <Title>MASTERDB.SDE.BATTALION_BOUNDARY</Title>
      <Abstract />
      <Keywords />
      <SRS>EPSG:4326</SRS>
      <LatLongBoundingBox minx="21.813" miny="8.641" maxx="27.907"
        maxy="20.002" />
    </FeatureType>
  - <FeatureType>
      <Name>MasterThesis:MASTERDB.SDE.CPC</Name>
      <Title>MASTERDB.SDE.CPC</Title>
      <Abstract />
      <Keywords />
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      <LatLongBoundingBox minx="22.254" miny="11.252" maxx="26.997"
        maxy="15.072" />
    </FeatureType>
  - <FeatureType>
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      <Title>MASTERDB.SDE.INCIDENTS_DATABASE</Title>
      <Abstract />
      <Keywords />
      <SRS>EPSG:4326</SRS>
      <LatLongBoundingBox minx="22.35" miny="10.863" maxx="26.206" maxy="14.56" />
    </FeatureType>
  - <FeatureType>
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      <Title>MASTERDB.SDE.UNAMID_CAMPS_POINT</Title>
      <Abstract />
      <Keywords />
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  - <FeatureType>
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      <Abstract />
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        maxy="15.071" />
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      <Title>battalion_boundary</Title>
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```

```xml
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          <ogc:Crosses />
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          <ogc:Contains />
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          <ogc:BBOX />
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    - <ogc:Scalar_Capabilities>
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```

```
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```

```xml
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