Online Live Street watch application supported by LTE-A & Automated Switching to Selected UE Mode of Operation for Restricted Area in LTE

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A Dissertation on

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List of Acronyms

LTE- Long Term Evolution
GPS- Global Positioning System
GPRS- General Packet Radio Service
GSM- Global System For Mobile
EPS- Evolved Packet System
UMTS- Universal Mobile Terrestrial System
WCDMA- Wideband Code Division Multiple Access
TDMA -Time Division Multiple Access.
OFDMA-Orthogonal Frequency Division Multiple Access
eNB- evolved NodeB
UTRA- Universal Terrestrial Radio Access
E-UTRA- Evolved Universal Terrestrial Radio Access
CA- Carrier Aggregation
RN- Relay Nodes
OLSW- Online live street watch
LFMCW- Live captures from a high resolution Linear Frequency Modulated Continuous Wave
RAN- Radio access network
CPE- A customer premises equipment
TTT- Time To Trigger
RSRP- Reference Signal Receive Power
UE- User Equipment

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Abstract

The online applications for street information have gained much popularity and wide use recently. The growing data rate of cellular services at affordable cost is supporting such applications. The Long Term Evolution (LTE) and its later version, LTE-Advanced (LTE-A) are now the most promising technologies for the cellular services. The street information, presently available online for general users, is either limited or not presented in enough user-friendly way. In this paper, we discuss a user-friendly approach for an application that provides online live view of the streets disseminating a lot of information. We analyze the potential usefulness of this application. We consider the use of LTE-A to upload video data from traffic cameras for the application. We propose a method to configure less frequent transmission of cell measurement reports in LTE-A in order to save wireless resources and power during this video data upload.

Chapter 1

Introduction

A good number of applications exist today to disseminate information about streets. This can primarily help decide the route for transport and thus, can save cost and time. However, most of the present applications primarily provide street locations with little information about the conditions of the streets. In practice, the current street conditions, especially in urban areas, can be pivotal in the decision for route. Considering the requirement of current and detailed information, a live view of the streets using traffic cameras, can be most useful. A convenient way to receive the street information can be online access from a website. Only a few websites so far provides live street view and their approaches are not enough user-friendly [1]. In this paper, we suggest the use of a user-friendly method for an application, particularly suitable as a mobile app, which offers online web access for live view of the major parts of the streets and highways. The application is termed online live street watch (OLSW) in this paper. The OLSW uses a 2D map view as the web interface from where the user can open up live view by clicking a point on the street. As the serving network infrastructure to support video data upload for OLSW, we select LTE-Advanced (LTEA) in the description but any high speed wireless network can be employed. LTE and LTE-A are the latest steps in the evolution of cellular services and their underlying advanced technologies enable them to provide high data rate at affordable costs [2]. For street information, the most popular application is now Google map, which covers the geographical map of around 220 countries and over 15,000 cities. It contains the information of more than 100 million places [3]. Google street view, incorporated with Google map, gives panoramic view of the streets. Using GPS based location information, Google map can provide voice guided directions for navigation, which can be used for walking, biking or driving. There are also OpenStreetMap, Bing maps, MapQuest, Mapline, Wikimapia, Apple maps and Umap as popular applications for street information and some of them are available only in particular areas. Some websites indicates accidents and similar incidents in the streets [4], [5]. Some websites provide still images from traffic cameras at different times of the day [6]. However, the information from these applications is usually limited and the user may not get a complete idea at the moment when he is taking a decision. The OLSW overcomes this limitation by allowing the user to watch live view of the street. There are various technologies, except traffic cameras, to collect street traffic information. The microwave sensors and magnetic loop detectors are two of the common technologies for monitoring streets [7]. However, they are required to be installed in a lane under the road surface using a labor intensive earth work. It also causes the disruption of traffic flow. These limitations have been overcome in some recent nonintrusive traffic monitoring technologies. The road traffic can be determined using a microphone array detecting the sound waves generated by the road vehicles. From the detected signals, the speed and density of vehicles on the road are determined using a correlation based algorithm [8]. The high resolution radars can also be used to monitor the road traffic. But the radar radiates probing beam on to the lane and it must be ensured that they do not cause interferences with other existing applications. Also, the installation cost of radar makes in unreasonable for deployment in many countries. Besides, laser, infrared and ultrasound can be used to detect the road traffic but for the best performance, the devices need to be mounted over the lane on some structure. In monitoring

Chapter 2
Long Term Evolution (LTE)

2.1Introduction

LTE is commonly marketed as 4G LTE, but it does not meet the technical criteria of a 4G wireless service, as specified in the 3GPP Release 8 and 9 document series, for LTE Advanced. The requirements were originally set forth by the ITU-Reorganization in the IMT Advanced specification. However, due to marketing pressures and the significant advancements that WiMAX, Evolved High Speed Packet Access and LTE bring to the original 3G technologies, ITU later decided that LTE together with the aforementioned technologies can be called 4G technologies. The LTE Advanced standard formally satisfies the ITU-R requirements to be considered IMT-Advanced.[4] To differentiate LTE Advanced and WiMAX-Advanced from current 4G technologies, ITU has defined them as "True 4G"

LTE:

Long-Term Evolution (LTE) is a standard for high-speed wireless communication for mobile phones and data terminals. It is based on the GSM/EDGE and UMTS/HSPA network technologies increasing the capacity and speed using a different radio interface together with core network improvements.[1][2] The standard is developed by the 3GPP (3rd Generation Partnership Project) and is specified in its Release 8 document series, with minor enhancements described in Release 9. Y LTE is the upgrade same for carriers with both GSM/UMTS networks and CDMA2000 networks. The different LTE frequencies and bands used in different countries will mean that only multi-band phones will be able to use LTE in all countries where it is supported.

Motivation for LTE

1. Need to ensure the continuity of competitiveness of the 3G system for the future
2. User demand for higher data rates and quality of service
3. Packet Switch optimized system
4. Continued demand for cost reduction (CAPEX and OPEX)
5. Low complexity
6. Avoid unnecessary fragmentation of technologies for paired and unpaired band operation

2.2 LTE Overview

LTE (Long Term Evolution) or the E-UTRAN (Evolved Universal Terrestrial Access Network), introduced in 3GPP R8, is the access part of the Evolved Packet System (EPS). The main requirements for the new access network are high spectral efficiency, high peak data rates, short round trip time as well as flexibility in frequency and bandwidth.

GSM was developed to carry real time services, in a circuit switched manner (blue in figure 1), with data services only possible over a circuit switched modem connection, with very low data rates. The first step towards an IP based packet switched (green in figure 1) solution was taken with the evolution of GSM to GPRS, using the same air interface and access method, TDMA (Time Division Multiple Access).

To reach higher data rates in UMTS (Universal Mobile Terrestrial System) a new access technology WCDMA (Wideband Code Division Multiple Access) was developed. The access network in UMTS emulates a circuit switched connection for real time services and a packet switched connection for datacom services (black in figure 1). In UMTS the IP address is allocated to the UE when a datacom service is established and released when the service is released. Incoming datacom services are therefore still relying upon the circuit switched core for paging.

The Evolved Packet System (EPS) is purely IP based. Both real time services and datacom services will be carried by the IP protocol. The IP address is allocated when the mobile is switched on and released when switched off.
The new access solution, LTE, is based on OFDMA (Orthogonal Frequency Division Multiple Access) and in combination with higher order modulation (up to 64QAM), large bandwidths (up to 20 MHz) and spatial multiplexing in the downlink (up to 4x4) high data rates can be achieved. The highest theoretical peak data rate on the transport channel is 75 Mbps in the uplink, and in the downlink, using spatial multiplexing, the rate can be as high as 300 Mbps.

The LTE access network is simply a network of base stations, evolved NodeB (eNB), generating a flat architecture (figure 2). There is no centralized intelligent controller, and the eNBs are normally inter-connected viathe X2-interface and towards the core network by the S1-interface (figure 2). The reason for distributing the intelligence amongst the base-stations in LTE is to speed up the connection set-up and reduce the time required for a handover. For an end-user the connection set-up time for a real time data session is in many cases crucial, especially in on-line gaming. The time for a handover is essential for real-time services where end-users tend to end calls if the handover takes too long.

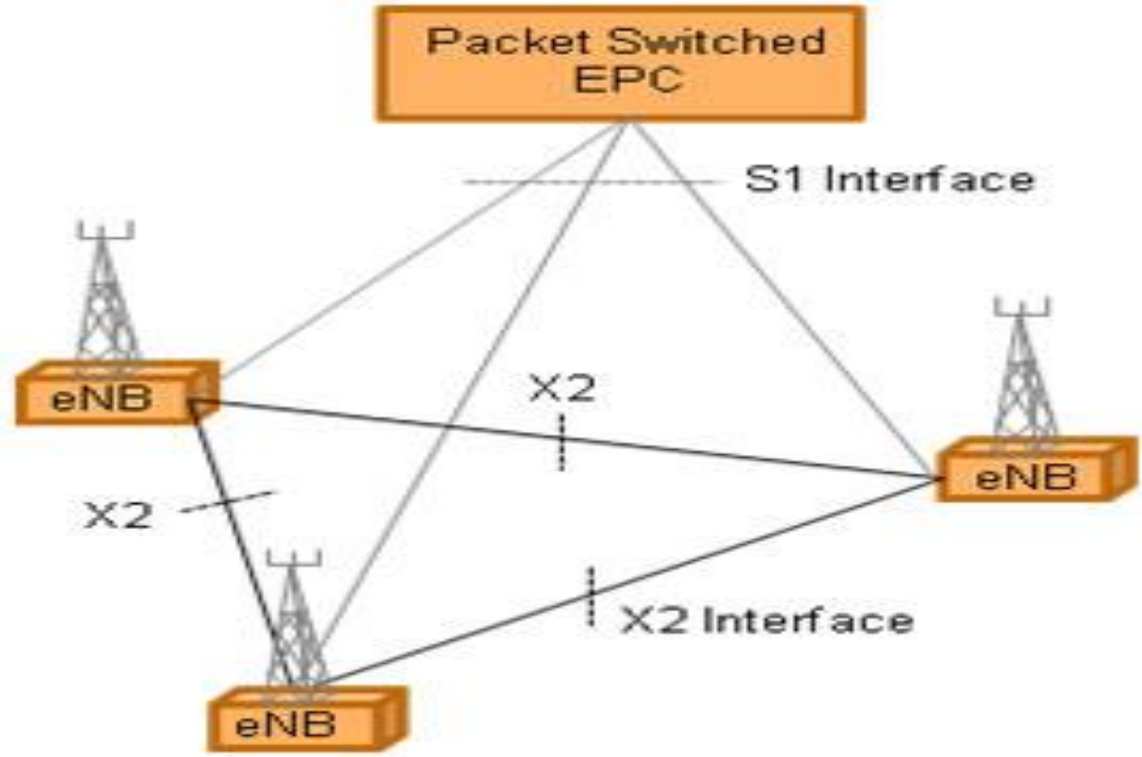

Figure 2.1: X2 and S1 Interfaces

2.3 LTE Historical Information

The technical paper UTRA-UTRAN Long Term Evolution (LTE) and 3GPP System Architecture Evolution (SAE) is a good starting point.
Initiated in 2004, the Long Term Evolution (LTE) project focused on enhancing the Universal Terrestrial Radio Access (UTRA) and optimizing 3GPP's radio access architecture.

The 3GPP 36 series of specifications, covers the "Evolved Universal Terrestrial Radio Access (E-UTRA)".
See also - the technologies page on LTE-Advanced, which describes the work beyond LTE Release8

2.4 What's the difference between 4G and LTE?

The ITU-R set standards for 4G connectivity in March of 2008, requiring all services described as 4G to adhere to a set of speed and connection standards. For mobile use, including smartphones and tablets, connection speeds need to have a peak of at least 100 megabits per second, and for more stationary uses such as mobile hotspots, at least 1 gigabit per second.
When these standards were announced, these speeds were unheard of in the practical world, because they were intended as a target for technology developers, a point in the future that

marked a significant jump over the current technology. Over time, the systems that power these networks have caught up, not just in the sense that new broadcasting methods have found their way into products, but the previously-established 3G networks have been improved to the point that they can be classified as 4G.

LTE stands for Long Term Evolution, and isn’t as much a technology as it is the path followed to achieve 4G speeds. As it stands, most of the time when your phone displays the “4G” symbol in the upper right corner, it doesn’t really mean it. When the ITU-R set the minimum speeds for 4G, they were a bit unreachable, despite the amount of money tech manufacturers put into achieving them. In response, the regulating body decided that LTE, the name given to the technology used in pursuit of those standards, could be labeled as 4G if it provided a substantial improvement over the 3G technology.

Immediately networks began advertising their connections as 4G LTE, a marketing technique that allowed them to claim next-gen connectivity without having to reach the actual required number first; it would be like the U.S. claiming they had landed on the moon because they got pretty close and the spaceship that got them there was a lot better than the previous ship. It’s not entirely trickery though, despite inconsistent speeds depending on location and network, the difference between 3G and 4G is immediately noticeable.

2.5 Patents

According to the European Telecommunications Standards Institute's (ETSI) intellectual property rights (IPR) database, about 50 companies have declared, as of March 2012, holding essential patents covering the LTE standard. The ETSI has made no investigation on the correctness of the declarations however,[120] so that "any analysis of essential LTE patents should take into account more than ETSI declarations."

The table below shows the available LTE royalty:

Announced royalty rates for LTE patents

Company	**Royalty rate**
Alcatel-Lucent	2.00%
Ericsson	1.50%
Huawei Technologies Co., Ltd.	1.50%
Inter Digital Inc.	2.50%
Motorola Inc.	2.25%
Motorola Mobility Inc.	2.25%
Nokia Corporation	1.50%
Nokia Siemens Networks	0.80%
Nortel Networks Ltd	1.00%
Qualcomm Incorporated	3.25%
Samsung Electronics Co., Ltd.	2.40%

Table 2.1 Announced royalty rates for LTE patents

Chapter 3
LTE Advanced

3.1 Introduction

In LTE-Advanced focus is on higher capacity:The driving force to further develop LTE towards LTE–Advanced - LTE Release10 was to provide higher bitrates in a cost efficient way and, at the same time, completely fulfil the requirements set by ITU for IMT Advanced, also referred to as 4G.

- Increased peak data rate, DL 3 Gbps, UL 1.5 Gbps
- Higher spectral efficiency, from a maximum of 16bps/Hz in R8 to 30 bps/Hz in R10
- Increased number of simultaneously active subscribers
- Improved performance at cell edges, e.g. for DL 2x2 MIMO at least 2.40 bps/Hz/cell.

The main new functionalities introduced in LTE-Advanced are Carrier Aggregation (CA), enhanced use of multi-antenna techniques and support for Relay Nodes (RN).

3.2 Carrier Aggregation

The most straightforward way to increase capacity is to add more bandwidth. Since it is important to keep backward compatibility with R8 and R9 mobiles the increase in bandwidth in LTE-Advanced is provided through aggregation of R8/R9 carriers. Carrier aggregation can be used for both FDD and TDD.

Each aggregated carrier is referred to as a component carrier. The component carrier can have a bandwidth of 1.4, 3, 5, 10, 15 or 20 MHz and a maximum of five component carriers can be aggregated. Hence the maximum bandwidth is 100 MHz. The number of aggregated carriers can be different in DL and UL, however the number of UL component carriers is never larger than the number of DL component carriers. The individual component carriers can also be of different bandwidths, see figure 1.

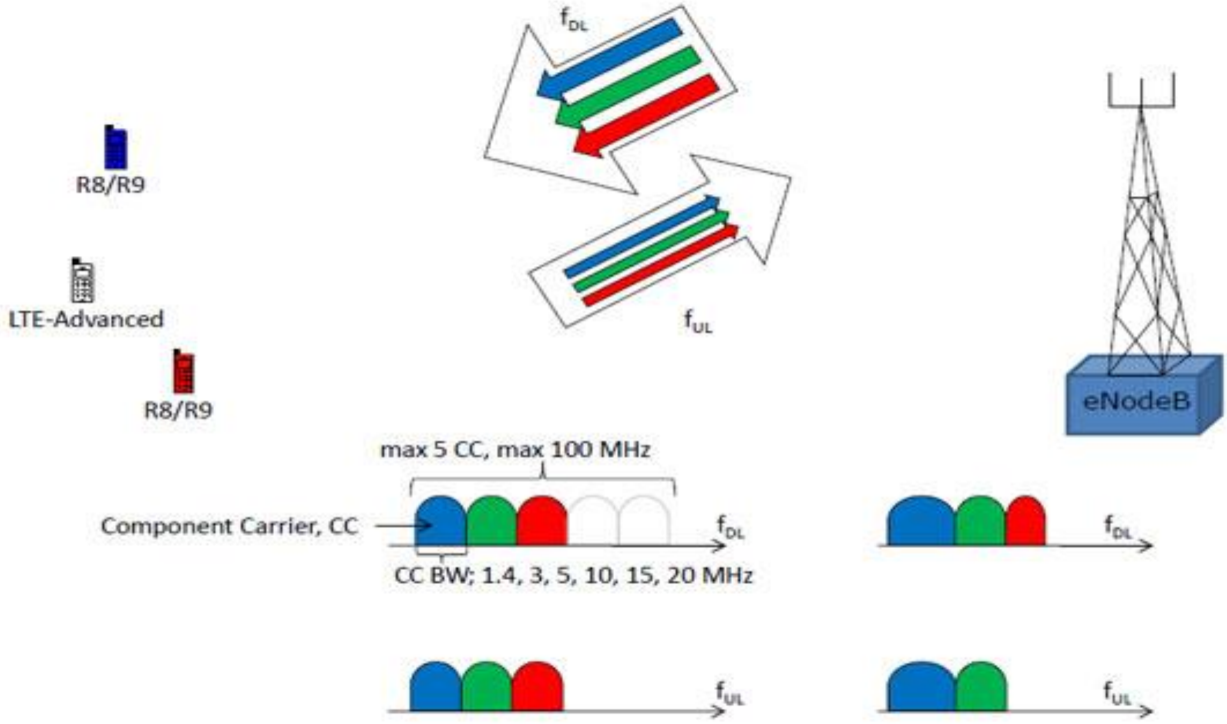

Figure 3.1: Carrier Aggregation

For practical reasons different carrier aggregation configurations – specified by e.g. combinations of E-UTRA operating band and the number of component carriers - are introduced in steps. In R10 there are two component carriers in the DL and only one in the UL (hence no carrier aggregation in the UL), in R11 there are two component carriers DL and one or two component carriers in the UL when carrier aggregation is used.

The easiest way to arrange aggregation is to use contiguous component carriers within the same operating frequency band (as defined for LTE), so called intra-band contiguous. This might not always be possible, due to frequency allocation scenarios. For non-contiguous allocation it could either be intra-band, i.e. the component carriers belong to the same operating frequency band, but are separated by a frequency gap, or it could be inter-band, inwhich case the component carriers belong to different operating frequency bands, see

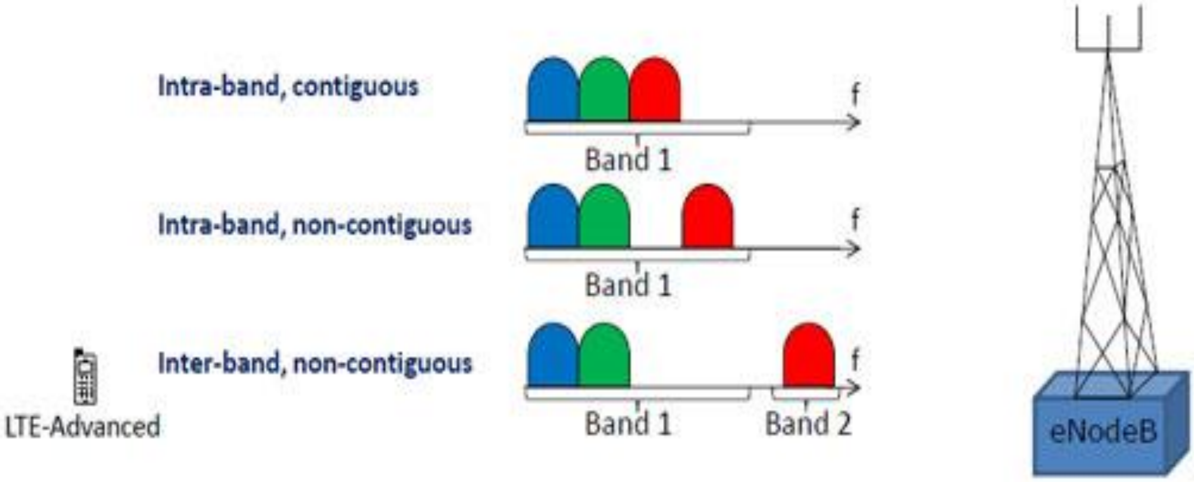

Figure 3.2: Carrier Aggregation- intra inter band alternative

3.3 What is LTE Advanced?

In short, a fancy name for using new technology to make existing LTE (4G) wireless connections faster. LTE Advanced can refer to all sorts of improvements to LTE, and the only real common factor is that they're all backwards-compatible with other LTE technology. In this case, it refers to combining multiple channels to send mobile data as quickly as possible. Verizon is claiming a 50 percent faster peak speed for its technology.

3.4 How does it work?

Verizon's technology is called "carrier aggregation," and it really isn't that hard to understand. Verizon owns multiple bands of spectrum, and normally, your device just uses the strongest signal. Using carrier aggregation, Verizon sends and receives packets on two or three channels at once, increasing the peak speed you can get under optimal conditions.

3.5 How fast is it?

Verizon claims that under optimal conditions, two-channel aggregation will hit speeds of 225Mbps, and three-channel aggregation over 300Mbps. That’s significantly faster than most home broadband, and faster than you will ever possibly need on a smartphone. It reality, it’s the difference between downloading an app in 20 seconds or 35.

3.6 How is LTE-Advanced different from regular LTE?

Just as many consumers are getting their first taste of speedy 4G LTE connections, carriers around the globe have begun pouring resources into building LTE-Advanced networks, which promise even faster and more reliable mobile access.

If you’re finding yourself confused by the alphabet soup of acronyms and technobabble, take heart: You are not alone. Let us help you with your many, many questions.

LTE stands for “long term evolution.” It’s a type of wireless technology that has taken hold throughout North America and is fast becoming a global standard.

LTE-Advanced (LTE-A) is an emerging and, as the name suggests, a more advanced set of standards and technologies that will be able to deliver bigger and speedier wireless-data payloads.

3.7 How does LTE-A work?

LTE-A incorporates of a number of techniques and technologies (hardware and software) that work in concert to meet higher network-performance standards. For all the in-depth techno-details, check out a list of the techniques involved.

Many technologies make up LTE-A. It’s not just one thing. But common themes include the ability to squeeze more bits into each megahertz of frequency, to bind together separate frequency bands, to make better use of multiple antennas, and to make better use of radio base stations and cells to provide broader coverage.

Although Sprint (the carrier that came in dead last in our most recent round of nationwide speed tests) is not using the LTE-A label, it is rolling out a new service called Sprint Spark that will allow devices to access three separate bandwidths of LTE at the same time. This stitching together of LTE bands, known as “carrier aggregation,”.

Chapter 4
Street View Apps

4.1 Introduction

The online applications for street information have gained much popularity and wide use recently. The growing data rate of cellular services at affordable cost is supporting such applications. The Long Term Evolution (LTE) and its later version, LTE-Advanced (LTE-A) are now the most promising technologies for the cellular services. The street information, presently available online for general users, is either limited or not presented in enough user-friendly way. In this paper, we discuss a user-friendly approach for an application that provides online live view of the streets disseminating a lot of information. We analyze the potential usefulness of this application. We consider the use of LTE-A to upload video data from traffic cameras for the application. We propose a method to configure less frequent transmission of cell measurement reports in LTE-A in order to save wireless resources and power during this video data upload.

4.2 Google Maps

Google Maps is a desktop web mapping service developed by Google. It offers satellite imagery, street maps, 360° panoramic views of streets (Street View), real-time traffic conditions (Google Traffic), and route planning for traveling by foot, car, bicycle (in beta), or public transportation.

Google Maps began as a C++ desktop program designed by Lars and Jens Eilstrup Rasmussen at Where 2 Technologies. In October 2004, the company was acquired by Google, which converted it into a web application. After additional acquisitions of a geospatial data visualization company and a real time traffic analyzer, Google Maps was launched in February 2005.[1] The service's front end utilizes JavaScript, XML, and Ajax. Google Maps offers an API that allows maps to be embedded on third-party websites,[2]and offers a locator for urban businesses and other organizations in numerous countries around the world. Google Map Maker allows users to collaboratively expand and update the service's mapping worldwide.

Google Maps' satellite view is a "top-down" or "birds eye" view; most of the high-resolution imagery of cities is aerial photography taken from aircraft flying at 800 to 1,500 feet (240 to 460 m), while most other imagery is from satellites.[3] Much of the available satellite imagery is no more than three years old and is updated on a regular basis.[4] Google Maps uses a close variant of the Mercator projection, and therefore cannot accurately show areas around the poles.

The current redesigned version of the desktop application was made available in 2013, alongside the "classic" (pre-2013) version. Google Maps for mobile was released in September 2008 and features GPS turn-by-turn navigation. In August 2013, it was determined to be the world's most popular app for smartphones, with over 54% of global smartphone owners using it at least once.

In 2012, Google reported having over 7,100 employees and contractors directly working in mapping.

4.3 Google Earth

Google Earth is a virtual globe, map and geographical information program that was originally called Earth Viewer 3D created by Keyhole, Inc, a Central Intelligence Agency (CIA) funded company acquired by Google in 2004 (see In-Q-Tel). It maps the Earth by the superimposition of images obtained from satellite imagery, aerial photography and geographic information system (GIS) onto a 3D globe. It was originally available with three different licenses, but has since been reduced to just two: Google Earth (a free version with limited function) and Google Earth Pro, which is now free (it previously cost $399 a year) and is intended for commercial use. The third original option, Google Earth Plus, has been discontinued.

The product, re-released as Google Earth in 2005, is available for use on personal computers running Windows 2000 and above, Mac OS X 10.3.9 and above, Linux kernel: 2.6 or later (released on June 12, 2006), and FreeBSD. Google Earth is also available as a browser plugin which was released on May 28, 2008. It was also made available for mobile viewers on the iPhone OS on October 28, 2008, as a free download from the App Store, and is available to Android users as a free app in the Google Play store. In addition to releasing an updated Keyhole based client, Google also added the imagery from the Earth database to their web-based mapping software, Google Maps. The release of Google Earth in June 2005 to the public caused a more than tenfold increase in media coverage on virtual globes between 2004 and 2005, driving public interest in geospatial technologies and applications. As of October 2011, Google Earth has been downloaded more than a billion times.

Google Earth displays satellite images of varying resolution of the Earth's surface, allowing users to see things like cities and houses looking perpendicularly down or at an oblique angle (see also bird's eye view). The degree of resolution available is based somewhat on the points of interest and popularity, but most land (except for some islands) is covered in at least 15 meters of resolution. Maps showing a visual representation of Google Earth coverage Melbourne, Victoria, Australia; Las Vegas, Nevada, United States; and Cambridge, Cambridge shire, United Kingdom include examples of the highest resolution, at 15 cm (6 inches). Google Earth allows users to search for addresses for some countries, enter coordinates, or simply use the mouse to browse to a location.

For large parts of the surface of the Earth only 2D images are available, from almost vertical photography. Viewing this from an oblique angle, there is perspective in the sense that objects which are horizontally far away are seen smaller, like viewing a large photograph, not quite like a 3D view.

For other parts of the surface of the Earth, 3D images of terrain and buildings are available. Google Earth uses digital elevation model (DEM) data collected by NASA's Shuttle Radar Topography Mission (SRTM). This means one can view almost the entire earth in three dimensions. Since November 2006, the 3D views of many mountains, including Mount Everest, have been improved by the use of supplementary DEM data to fill the gaps in SRTM coverage.

Some people use the applications to add their own data, making them available through various sources, such as the Bulletin Board Systems (BBS) or blogs mentioned in the link section below. Google Earth is able to show various kinds of images overlaid on the surface of the earth and is also a Web Map Service client. Google Earth supports managing three-dimensional Geospatial data through Keyhole Markup Language (KML).

4.4 OpenStreetMap

OpenStreetMap (OSM) is a collaborative project to create a free editable map of the world. The creation and growth of OSM has been motivated by restrictions on use or availability of map information across much of the world, and the advent of inexpensive portable satellite navigation devices. OSM is considered a prominent example of volunteered geographic information.

Created by Steve Coast in the UK in 2004, it was inspired by the success of Wikipedia and the predominance of proprietary map data in the UK and elsewhere. Since then, it has grown to over 2 million registered users, who can collect data using manual survey, GPS devices, aerial photography, and other free sources. These crowd sourced data are then made available under the Open Database Licence. The site is supported by the OpenStreetMap Foundation, a non-profit organization registered in England and Wales.

Rather than the map itself, the data generated by the OpenStreetMap project are considered its primary output. The data are then available for use in both traditional applications, like its usage by Craigslist, OSM And, Geocaching, MapQuest Open, JMP statistical software, and Foursquare to replace Google Maps, and more unusual roles like replacing default data included with GPS receivers. OpenStreetMap data have been favourably compared with proprietary datasources though data quality varies worldwide.

4.5 Google Street View

Google Street View is a technology featured in Google Maps and Google Earth that provides panoramic views from positions along many streets in the world. It was launched in 2007 in several cities in the United States, and has since expanded to include cities and rural areas worldwide. Streets with Street View imagery available are shown as blue lines on Google Maps.

4.6 Wikimapia

Google Street View displays panoramas of stitched images. Most photography is done by car, but some is done by trekker, tricycle, walking, boat, snowmobile, and underwater apparatus.

Wikimapia is a privately owned open-content collaborative mapping project, that utilizes an interactive "clickable" web map with a geographically-referenced wiki system, with the aim to mark and describe all geographical objects in the world.

Created by Alexandre Koriakine and Evgeniy Saveliev on May 2006, since then it has become a popular mapping website. The data, a crowd sourced collection of places marked by registered users and guests, has grown to over 25,000,000 objects as of August 2015, and is released under the Creative Commons License Attribution-Share Alike (CC BY-SA).

Although the project's name is reminiscent to that of Wikipedia and that the creators share the "wiki" philosophy, it is not a part of the non-profit Wikimedia Foundation family of wikis.

4.7 Apple Maps

Apple Maps is a web mapping service developed by Apple Inc. It is the default map system of iOS, macOS, and watchOS. It provides directions and estimated times of arrival for automobile, pedestrian, and public transportation navigation. Apple Maps also features the unique 'Flyovers' mode, a feature that enables a user to explore densely populated urban centers in a 3D landscape composed of models of buildings and structures.

On September 19, 2012, Apple released its mapping service in iOS, replacing Google Maps as the default mapping service for Appleoperating systems. In the initial launch, it received large amounts of criticism from users and newspapers for incorrect directions, a lack of support for public transportation users and various other bugs and errors. Since its introduction, further software development has addressed many of those criticisms.

4.8 MapQuest

MapQuest (stylized as mapquest) is an American free online web mapping service owned by AOL. The company was founded in 1967 as Cartographic Services, a division of R.R. Donnelley & Sons in Chicago, Illinois, United States. It moved to Lancaster, Pennsylvania in 1969. When it became an independent company in 1994, it was renamed GeoSystems Global Corporation. MapQuest was acquired in 2000 by America Online, Inc. Company headquarters are in Denver, Colorado. As of May 2015, it had the second-highest share of the online mapping market in the United States, second only to Google Maps.

Chapter 5
OLSW

5.1 Introduction

A good number of applications exist today to disseminate information about streets. This can primarily help decide the route for transport and thus, can save cost and time. However, most of the present applications primarily provide street locations with little information about the conditions of the streets. In practice, the current street conditions, especially in urban areas, can be pivotal in the decision for route. Considering the requirement of current and detailed information, a live view of the streets using traffic cameras, can be most useful. A convenient way to receive the street information can be online access from a website. Only a few websites so far provides live street view and their approaches are not enough user-friendly. In this paper, we suggest the use of a user-friendly method for an application, particularly suitable as a mobile app, which offers online web access for live view of the major parts of the streets and highways. The application is termed online live street watch (OLSW) in this book. The OLSW uses a 2D map view as the web interface from where the user can open up live view by clicking a point on the street. As the serving network infrastructure to support video data upload for OLSW, we select LTE-Advanced (LTEA) in the description but any high speed wireless network can be employed. LTE and LTE-A are the latest steps in the evolution of cellular services and their underlying advanced technologies enable them to provide high data rate at affordable costs.

5.2 Available Models

<u>Microwave Sensors and Magnetic Loop Detectors:</u>

●It requires low maintenance and reliable.

●The drawback of this model is that it requires dig up the roads which is costly and during installation, it is burden for general people.

<u>Radar Gun and Pressure:</u>

●It could be another choice for controlling traffics

●But it transmits less amount of traffic information to the people.

Computer Vision:

●Another popular way of supervising traffic condition

●But it'll not applicable if weather and lighting condition varies

●Due to low installation cost and capability of accumulating huge amount of information like speed, flow rate and queue length,it's user friendly in lot of relevant cases

RFID and GPS :

● Radio Frequency Identification Technology (RFID Video processing, Global positioning system (GPS), intelligent traffic monitoring using MANET are widely used throughout the world to monitor traffics on the streets

Digital Sound Field Mapping*:*

●This technique utilizes a microphone array to detect the sound waves which is generated by road vehicles

●The important data are extracted from the detected signals which are digitized and processed by an on-site computer through a Correlation based algorithm.

●Though this model/technique is easy to understand for the engineers, it's not easily understandable to the general mass as lot of graphs and histogram was developed in this model

High Resolution Radars*:*

●Live captures from a high resolution Linear Frequency Modulated Continuous Wave (LFMCW) millimeter-wave radar is used in this type of module

●It's a very recent and well-furnished technology to monitor road traffic

●But installation cost of radar is not reasonable for all the countries.

5.3 Application Model

The proposed model for OLSW application sends the video data continuously from the traffic cameras to a data storage server as well as a data processing server. This can be conveniently performed using a high speed cellular network. As shown in Fig. 1, the video data will be routed to internet cloud via the radio access network (RAN) and core network (CN) of the cellular network. The arrows in this figure indicate the directions of data flow. The data storage and data processing servers receive the video data via an internet service provider (ISP). These servers will forward necessary data to the web server, which is accessed by the UEs. The data processing server picks images from the video data and performs vision based image processing using one of the available techniques to determine traffic density and average speed of the vehicles.

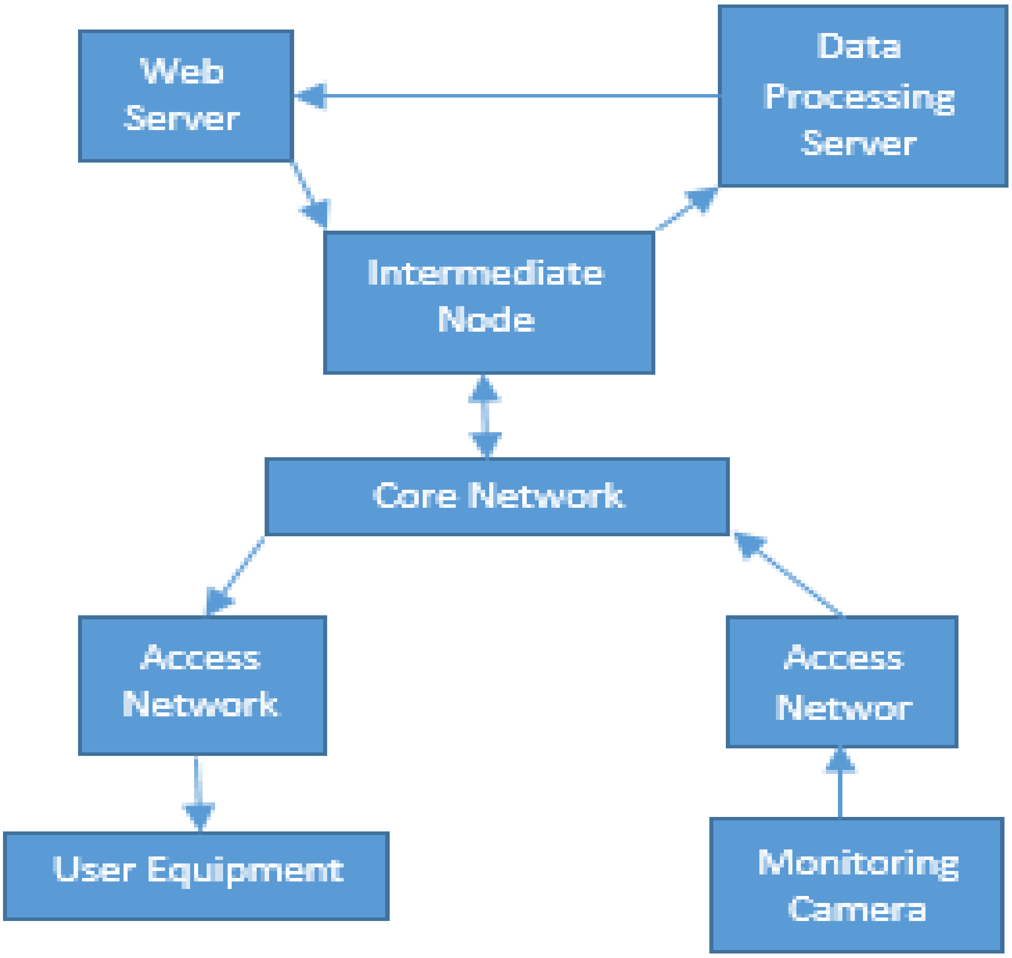

Fig 5.1: Block Diagram Indicating Data Flow among Different Entities for OLSW

The video data will be available online for users for live view. In the first website interface, a user finds a 2D map view of the area similar to what Google map and similar other applications provide. The parts of the streets for which video data are available, will be marked with arrows of different colors. When the user clicks a point from those parts of the streets, a live view will appear in a small window at a corner. The window for live view can be optionally extended to a full screen view. The traffic density is quantized and different colors are chosen for different threshold values of traffic density. The map view of the first web interface will have its streets marked with arrows of different colors according to the traffic directions and densities. This interface will also display average speed of the vehicles next to the streets. This will help the user get a quick idea about the street conditions at the early interface. Fig 5.2 exemplifies the application interfaces. Fig 5.3, 5.4, 5.5 shows the street views at different times of the day and the traffic density was small, medium and large at these different times. The street at Board Bazar, Gazipur-1704, Bangladesh, is used. The data processing server uses vision based image processing to determine various road incidents, in addition to traffic density and speed of the vehicles. Besides, news centers can be connected to the data processing server and provide information on the incidents. The incidents can include:

i. road accident,
ii. roadwork,
iii. public procession,
iv. public meeting,
v. violence and sabotage,
vi. Police cordon, etc.

It may not always be possible to identify the incidents automatically and manual intervention can sometimes be necessary. The map view of OLSW indicates the incidents in the streets using different symbols. The color of the symbol indicates whether the road is partially or fully blocked because of the particular incident. Some of these indications can be especially helpful when there are some security concerns.

Fig 5.2: First Web Interface for OLSW Showing Arrows and Symbols on the Map View

For Low Traffic Density

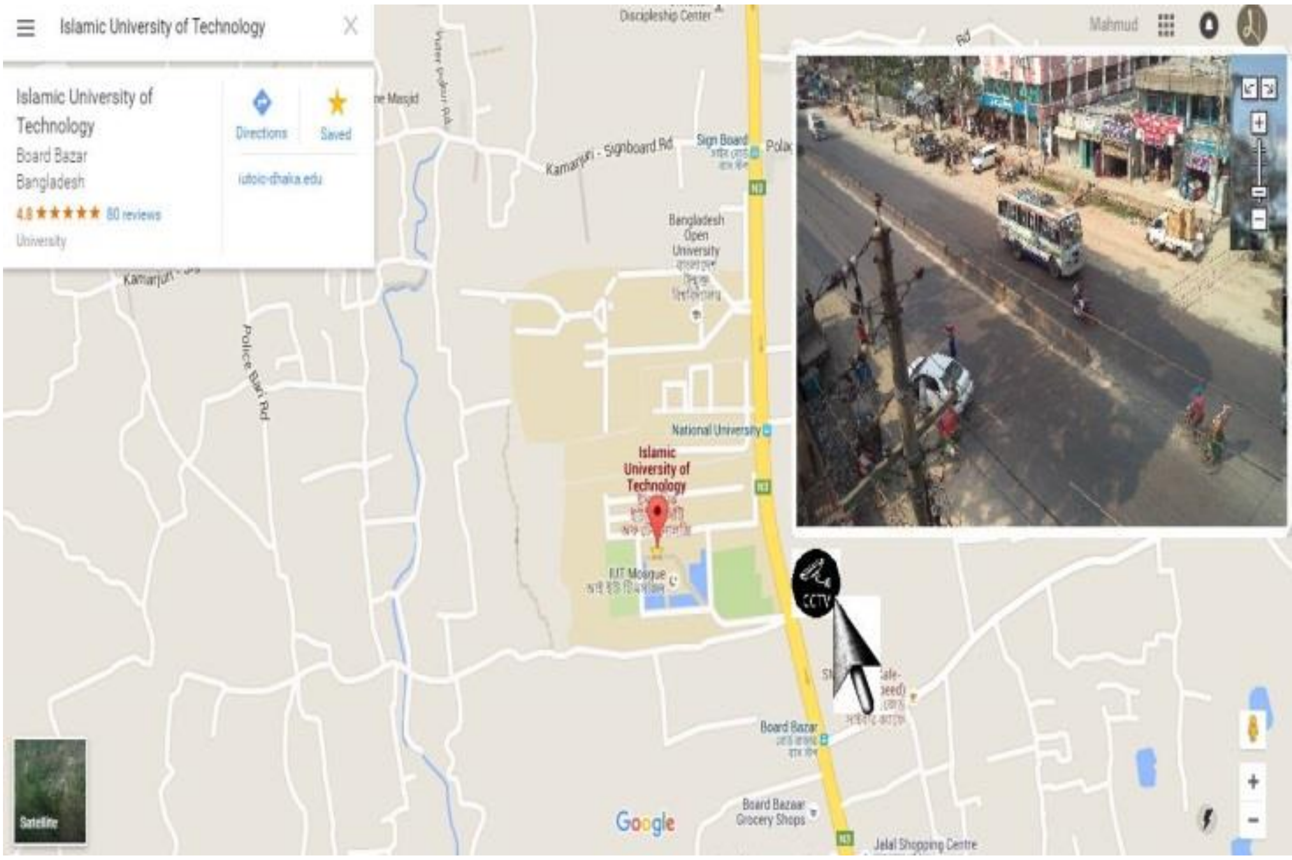

Fig 5.3: OLSW Interface with Low Traffic Density

For Medium Traffic Density

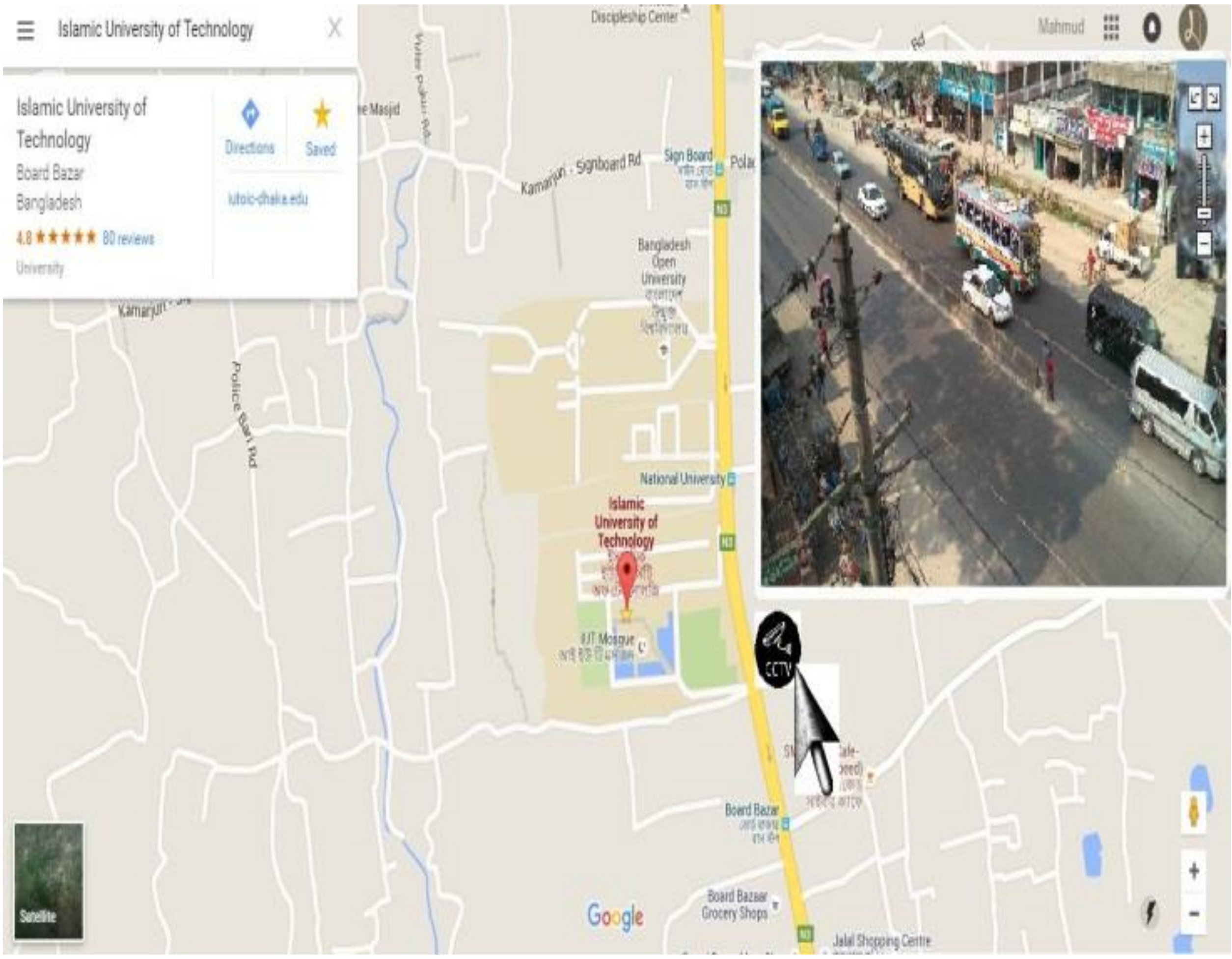

Fig 5.4: OLSW Interface with Medium Traffic Density

For High Traffic Density

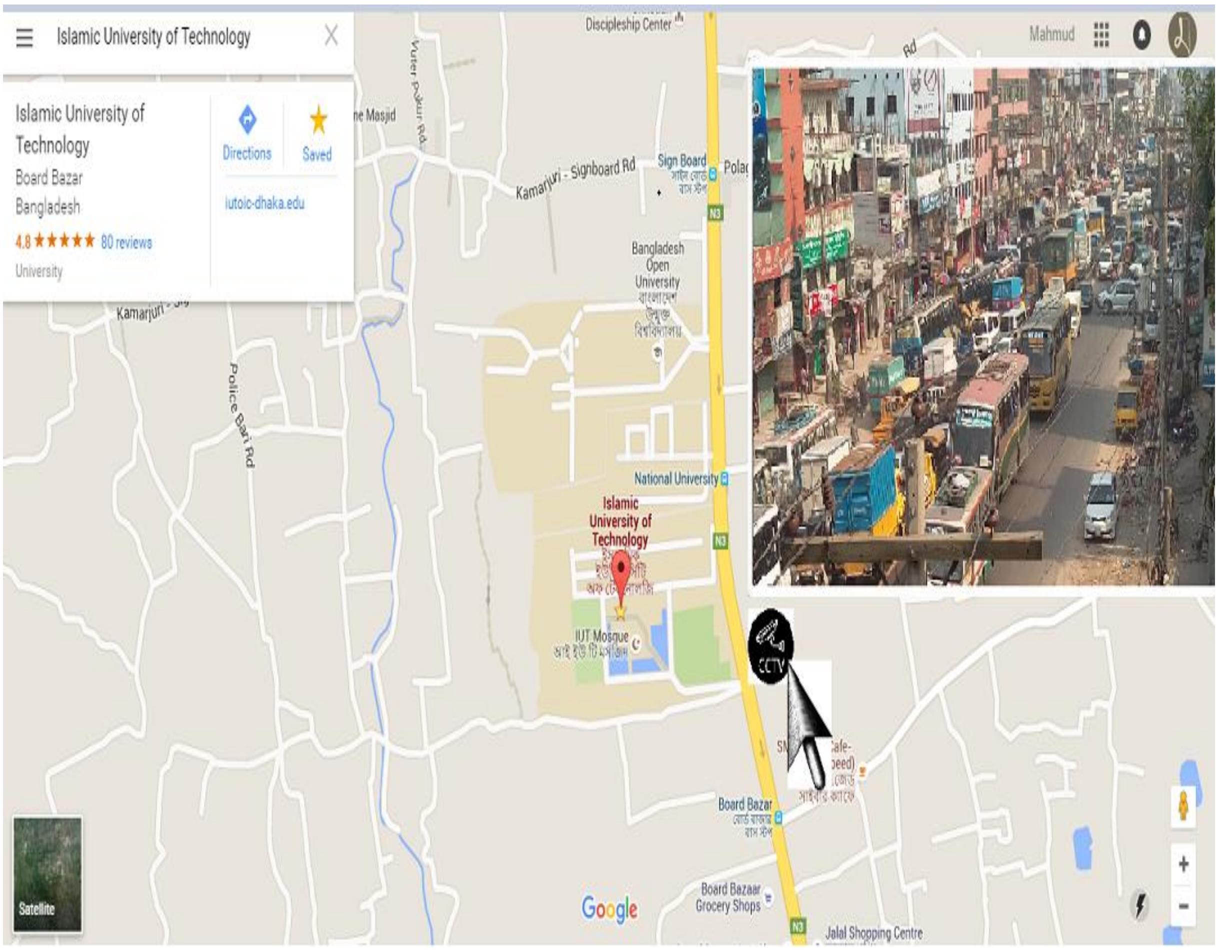

Fig 5.5: OLSW Interface with High Traffic Density

The uploaded video data will be stored in a data storage server. This can allow the user to view the streets in times past. The user can specify the date and time and then the web interface will start playing the recorded video of the street view from that moment showing the progress in time alongside. A customer premises equipment (CPE) needs to be installed along with the camera to upload the video data. Since this is an installation at a fixed location, the CPE can use highly directional antennas pointing to the base station. The installation of CPE and camera involves a good amount of investment. Therefore, depending on the priority of locations, the deployment of CPE and camera can gradually expand in the course of time. The deployment may first take only arterial roads into account, especially, covering the intersection of the major arterials with the urban freeways. Then the deployment can gradually cover selected areas of major streets and highways, for example, the signalized intersections around selected downtown areas and near the shopping malls, exhibition places, hospitals, airports, sports venues, etc. In time, the deployment can even cover less important areas of the streets. The position of the installed camera must be selected such that the view is not obstructed by the tree, canopy, adjacent buildings or other overhead structures. The higher the camera is mounted above the ground, the greater is the likelihood of wider camera view. It is often preferable for the camera to be mounted at the height of at 12m to 18m (40 ft. to 60 ft.) in order to provide a bird's eye view of the overall traffic. Optionally, the camera can keep changing its direction slowly so that a single camera can be used to cover a wide range of view. The cameras must not capture restricted zones or private areas.

5.4 Usefulness of OLSW application

The OLSW can potentially render manifold services and we derive some of these services below.

1. The primary use of OLSW will be to enable a user to select less crowded routes or routes free from any road blocks or other problems so that he can travel faster and more conveniently.

2. The selection of less crowded routes will help distribute the vehicles more uniformly among the streets. This can minimize traffic congestions in the streets and highways. Also, the traffic management will be easier and more effective.

3. Because the video data of the street views are stored, this data can later be used by the law enforcement agencies for various purposes as shown next.

i. When there has been any crime or misconduct in the streets, proper information about the misdeed can be derived and the criminals can be identified. ii. When a criminal has fled, the recorded video data may help track the criminal.

iii. In the cases when children or aged people have been lost, the recorded video data may help track them.

iv. In the cases when a person has been kidnapped, the recorded video data may help track the kidnappers.

v. When there has been any car accident, the recorded video data may help determine who is at fault in the accident and resolve arguments.

vi. Speeding drivers can be identified more easily. Plenty of surveillance cameras are already in use very successfully for this purpose.

vii. Drunk drivers can be identified more easily.

4. The live view can convey the information of road accidents faster and in better detail. Consequently, proper actions can be taken quicker to save lives.

5. The live view can convey the information of violence and sabotage in the streets faster and in better detail. Consequently, the relevant authorities can take proper actions quicker to save lives and properties. Besides, general people can avoid routes along these streets.

6. Detailed information of traffic flow patterns, traffic events, speed of the vehicles, and so forth, are made available to traffic management authorities, city planners and drivers. This can potentially help in many ways, for example, to improve road safety, improve traffic control and even develop new capabilities for intelligent vehicles.

5.5 Deployment Strategies

●The proposed application, OSM should be used to monitor the freeway and major street network as well as transit in almost all urban areas.

●Cameras typically monitor and communicate traffic conditions on freeways, highways and other major surface streets in the particular city or region.

General

The proposed strategy for the deployment of traffic surveillance cameras can be a two-step process; first one is to determine the arterial street routes to be monitored and second one is to determine the locations along the selected routes to place the camera.

Camera Deployment Strategy

Cameras will be deployed to view the traffic movement and queuing at the signalized intersections, along major arterial routes and at the intersection of the major arterials i.e. major arterials that intersect with the urban freeways, major arterials that is parallel with the urban freeways, adjacent to the exhibition places, market ,hospital, airport area and the various sports venues and the other major intersections based on the highest average 24 hours volume and most congested intersections locations.

Installation Guideline

- ▶ The Camera which is going to be used for OSM must be able to change its direction slowly
- ▶ These cameras should be installed in such a way that it only monitors those space that have been identified.
- ▶ The operation of the cameras should be restricted if possible so the operators can not adjust, zoom or manipulate the camera to overlook spaces that are not intended to be covered by the camera.
- ▶ Cameras should not monitor the inside of the areas where individuals generally have higher expectation of privacy (Example –Public washroom)

Camera mounting options

For the mounting of the cameras in the field, there are two key consideration; first one is the height at which the camera is mounted (and hence the viewing distance and angle).Another one is the rigidity of the camera mounting pole or base (for better image quality).

Height of the camera

The higher the camera is mounted above the ground, greater is the potential for longer and wider camera fields of view. It is often preferable for the camera to be mounted at the height of at 12m to 18m (40 ft. to 60 ft.) to provide a "bird's eye view" of the overall traffic flowing around the camera locations and possibly monitor adjacent intersections.

5.6MEASUREMENT REPORTING CONFIGURATION IN LTE-A FOR UPLINK DATA TRANSFER

We assume that the CPE installed with the camera for OLSW uses LTE-Advanced for video data upload. This uplink data transfer uses a communication between devices and a server without the need for human interaction, and thus, it is a Machine-to-Machine (M2M) communication. LTE-A is expected and widely acknowledged as the main enabler for the widespread emergence of M2M systems. For efficient M2M communication, there has been a growing need to develop new UE categories in LTE-A. Consequently, a new UE category has been developed meeting the requirements of general M2M communication and it is referred to as UE category 0, or simply UE cat 0. The cost of the modem for this UE category 0 is approximately 40-50% of regular LTE devices. The peak data rate for the UE category 0 is reduced to 1 Mbps, which is sufficient for video data upload. It can operate in half duplex mode, which is suitable for video data upload while saving cost and power [14]. Thus, the UE category 0 mostly matches the CPE requirements for video data upload for OLSW. However, for CPEs at fixed locations, it is possible to enhance the performance defining a new UE category, which can be a little modified form of UE category 0. It may be noted that M2M communication is defining LTEA as one of the main platforms for the Internet of Things (IoT) [14]. But there will be many different types of requirements in data transfer for IoT. So, we propose that multiple UE categories with different configurations should be defined to support the forthcoming various M2M communications and one of these UE categories should meet the requirements of CPEs at fixed locations as required for video data upload for OLSW. We assume that our proposed category for OLSW is UE category X. The UE category X performs cell measurement reporting as described below.

In LTE-A, the UE performs measurements of the radio link quality of serving and neighbor cells and sends measurement reports to the network. The network considers the radio link quality reported and makes the decision for handover. In the RRC_CONNECTED state, in a measurement period of 200 msec, the CPE or the UE performs measurements of at least 8 identified intra-frequency cells when no measurement gaps are activated. The UE sends the measurement reports to the eNodeB and the interval between consecutive measurement reports is configured by the eNodeB using ReportInterval field on a layer 3 message. The value of ReportInterval field can range from 120 ms to 1 hour. The measurement reporting consumes wireless resources and power as well.

For UEs at fixed locations, the handover is not usual. Thus, the cell measurements and its reporting will be of no use unless there is a major change in the network infrastructure or in the multipath environment. Therefore, for low-to-zero mobility devices with M2M communication, less frequent cell measurements is already under consideration to reduce power consumption. Thus, the measurement period for UE category X can be made much larger than 200 msec and we suggest that this is performed to save wireless resources and power. We propose that the eNodeB additionally sends a Report Interval Factor field on the layer 3 message. The UE category X uses an interval between consecutive measurement reports equal to the product of Report Interval and Report Interval Factor. Evidently, this will allow to conveniently adjust an increased interval between reporting for the UE category X and thus, save some wireless resources and power during video data upload for OLSW.

5.7 CONCLUSION

The OLSW application can be of great use especially, for city dwellers. The service can range from the daily commutes to the bulk business transport. However, the deployment and maintenance for OLSW requires a good amount of investment. Therefore, local government or welfare organizations can step forward to implement OLSW. The implementation project may also be public-private partnership (PPP). The proposed method to configure less frequent cell measurement reporting in LTE-A can potentially save wireless resources and power during the video data for OLSW.

Chapter6
Small Cell

6.1 Introduction

Small cells are low-powered radio access nodes that operate in licensed and unlicensed spectrum that have a range of 10 meters to 1 or 2 kilometers. They are "small" compared to a mobile macro cell, which may have a range of a few tens of kilometers. With mobile operators struggling to support the growth in mobile data traffic, many are using mobile data offloading as a more efficient use of radio spectrum. Small cells are a vital element to 3G data offloading, and many mobile network operators see small cells as vital to managing LTE Advanced spectrum more efficiently compared to using just macro cells.

6.2 What is a small cell?

Small cells are fully featured, short range mobile phone base stations used to complement mobile phone service from larger macrocell towers. These range from very compact residential femtocells, the size of a paperback book and connected using standard domestic internet broadband through to larger equipment used inside commercial offices or outdoor public spaces. They offer excellent mobile phone coverage and data speeds at home, in the office and public areas for both voice and data. Small cells have been developed for both 3G and the newer 4G/LTE radio technologies.

6.3 Locked to a single mobile phone network

Unlike Wi-Fi, these devices use licenced radio spectrum, so must be operated and controlled by a mobile phone company. Thus it will work with only one mobile phone operator, and thus encourages all users in a household or business enterprise to switch to the same network operator.

When in range of the small cell, the mobile phone will automatically detect it and use it in preference to the larger macrocell cell sites. Calls are made and received in exactly the same way as before, except that the signals are sent encrypted from the small cell via the public or private broadband IP network to one of the mobile operators main switching centres. Making and receiving calls uses the same procedures and telephone numbers, and all the standard features (call divert, text messaging, web browsing) are available in the same way - indeed data services should operate more quickly and efficiently due to the short range involved.

6.4 Low power but high quality

Small cells operate at very low radio power levels - less than cordless phones, Wi-Fi or some other household equipment. This substantially increases the battery life, both on standby and talktime. Since they are so much closer to the handset or mobile device, call quality is excellent and data devices can operate at full speed. The smallest femtocells can handle up to 4 simultaneous active calls from different users, with most indoor products having a standard capacity of 8. Larger small cell designs for business (enterprise) or public areas use can handle 16, 32 or more concurrent calls or data sessions. A few of the latest multi-mode 3G and LTE small cells can cope with up to 64 3G and 128 LTE concurrent active sessions. Some products can handle even more. These numbers are in addition to passive users not actively making or receiving voice or data calls.

6.5 Open or restricted access

Restrictions can be applied on who can access a small cell. Residential femtocell owners may be concerned about paying additional charges for wire line internet broadband where a quota applies - even though this would equate to many long voice calls or heavy data service use. For this reason, many residential femtocells include a facility to restrict service to a whitelist of up to 30 specified telephone numbers. Enterprise use is more commonly open to all, including visitors, but may prioritize phones belonging to the business itself. Urban and rural small cells are always fully open access.

6.6 Secure and self-managing

Small cells encrypt all voice and data sent and received, ensuring a high level of protection from sniffing or snooping.

In order to reduce operational and installation costs, these units are self installing and use a variety of clever tricks to sense which frequency to transmit on and power level to use.

Unlike large outdoor mobile phone base stations (masts), femtocells don't require specialist RF planning engineers to design, calibrate or configure themselves - minimizing the ongoing cost of maintaining them. They do have remote management from the network operator, who can upgrade the configuration and software as required.

6.7 Doesn't require special phones

They are compatible with existing standard 3G and 4G mobile phones and are not restricted to any specific models. No additional software is required to enable the phone to work with a small cell.

6.8 Technology

Most of the excitement originated around the 3G UMTS/HSPA mobile phone technology, deployed in almost every country worldwide today and which includes the ability for high speed data services. More recently LTE small cells have become available, with a few models capable of handling both. Generally speaking, 3G is more widely used indoors, with urban small cells focussed mostly on LTE. This is because of the tighter integration and co-ordination between streetside small cells and nearby macrocells sharing the same frequencies, something with LTE was designed specifically to cope with although there are a few 3G urban small cell deployments.

6.9 Types of small cell

1. Femtocell
2. Picocell
3. Microcell

1. Femtocell

A femtocell is a wireless access point that improves cellular reception inside a home or office building. The device, which resembles a wireless router, essentially acts as a repeater. The device communicates with the mobile phone and converts voice calls into voice over IP (VoIP) packets. The packets are then transmitted over a broadband connection to the mobile operator's servers. Femtocells are compatible with CDMA2000, WiMAX or UMTS mobile telephony devices, using the provider's own licensed spectrum to operate. Typically, consumer-oriented femtocells will support no more than four active users, while enterprise-grade femtocells can support up to 16 active users.

The name femtocell was derived from "cellular" and "femto," a metric prefix that stands for 10^-15th, or one-quadrillionth, six orders of magnitude smaller than nano. Femtocells were originally called access point base stations. The development of femtocells is credited, in part, to the work of a skunk works team at Motorola in the UK, where they created the world's smallest full power UMTS base station.

Standalone or integrated femtocells

Early residential femtocell products look very much like Wi-Fi broadband modems, needing only two cables - one for power and one internet connection.

In the past, several vendors such as Thomson, Netgear, Pirelli, Cisco and others integrated the femtocell with other features such as DSL modem, Wi-Fi and even IPTV into a single box. Virtually none of these combined solutions have succeeded. The vast majority of residential femtocells sold to date are standalone.

Larger enterprise and metrocells are also standalone, having sturdy casing and better protection against weather and operating in unsupervised areas.

2. Picocell

A picocell is a small mobile base station that improves in-building cellular coverage. Picocells have a range of up to 30,000 square feet and can support up to 100 users.

What’s the difference between picocells and femtocells?

Cellular systems increase capacity by reusing the same radio frequencies across many cellsites – in dense urban areas that means cellsites with coverage areas of as little as 200 metres. In order to provide adequate capacity, plus good in-building coverage (and thus quality), large numbers of small cellsites are required.

Macrocells are the original, wide area high power bases tations which cover areas up to about 20 miles radius (more in specific situation). In urban areas, a separate layer of microcells is installed to provide the capacity and in-building penetration needed, taking the load off the macrocellular network. For office buildings and shopping malls with extremely high demand, even smaller cell sites are used. All three types of cell operate in a very similar way, and are actively managed and configured by the mobile network operator. Each cell is configured with neighbour lists, so that mobile phones can switch over to an appropriate nearby cell and continue their conversation without interruption.

Picocells are normally installed and maintained directly by the network operator, who would pay for site rental, power and fixed network connections back their switching centre.

Femtocells differ from picocells because they are intended to be much more autonomous. They are self-installed by the end user in their home or office, primarily for their own benefit. Femtocells automatically determine which frequency and power levels to operate at, rather than being directed from a centrally determined master plan. This allows the network to adapt automatically as new femtocells are added or moved without the need for a complete frequency re-plan.

The disadvantage is that femtocells would not normally broadcast a list of nearby neighbouring cells. Mobile phones would thus maintain the connection on the femtocell as much as possible, but risk dropping the call or having an short outage if the call needs to be switched across to an external macro or microcell.

Femtocell vendors have been promoting the use of their products within the enterprise, in order to displace picocells. Their arguments are based on lower operational costs (ease of installation, ongoing maintenance etc.). The business case for femtocells in the enterprise is potentially stronger than for picocells, because of the lower installation and ongoing operational costs. It would piggyback on the existing IP network infrastructure provided by the business IT department, who could use mechanisms to prioritise the traffic above mainstream data traffic to ensure high voice quality. Corporations would expect to benefit from lower cost calls within their enterprise locations in return for installing and maintaining these systems, which would also be offset by not requiring fixed phones at the desk.

Table of differences between femtocells and picocells

Aspect	**Picocell**	**Femtocell**
Installation	Operator	Customer
Transmission to operator's network	Operator	Customer
Frequency/radio parameters	Centrally planned	Locally determined
Site rental	Operator	Customer

Table6.1: Table of differences between femtocells and picocells

3. Microcell

A microcell is a cell in a mobile phone network served by a low power cellular base station (tower), covering a limited area such as a mall, a hotel, or a transportation hub. A microcell is usually larger than a picocell, though the distinction is not always clear. A microcell uses power control to limit the radius of its coverage area.

Typically the range of a microcell is less than two kilometers wide, whereas standard base stations may have ranges of up to 35 kilometres (22 mi). A picocell, on the other hand, is 200 meters or less, and a femtocell is on the order of 10 meters, although AT&T calls its femtocell that has a range of 40 feet (12 m), a "microcell".AT&T uses "AT&T 3G MicroCell" as a trade mark and not necessarily the "microcell" technology.

Chapter7

LTE Small Cell vs Wi-Fi User Experience

7.1 Introduction

Industry predictions have shown that the future data services will lead to an exponential data traffic growth by 1000 times. According to these statistics, 80% of the traffic will be indoor and at hotspots. To meet the large capacity demand indoor and at hot spots, two popular solutions are now being discussed: expending the deployment of Wi-Fi, or deploying small cells based on enhancements of the cellular technology. Both systems keep evolving in the corresponding standard organizations, e.g. small cell enhancements for LTE, which are currently being standardized in 3GPP Rel-12 (to be frozen in 2014Q3), are also known as LTE-Hi; as well as IEEE802.11ac (to be frozen in 2014Q1) for Wi-Fi enhancement. This document provides an analysis and test results for the user experience of the commercial-level LTE small cell, as well as a comparison with the other small cell solution, namely Wi-Fi.

7.2 Performance Analysis and Evaluation

7.2.1 Test Environment & Scenarios

The performance comparison is based on LTE macro eNodeB and Wi-Fi Access Point (AP), where LTE is based on Rel-8 while Wi-Fi is based 802.11n.

The test environment is single cell scenario without inter-cell interference, with the detailed configurations listed in 7.1. These set of tests focus on single cell scenario, since Wi-Fi is mainly for indoor isolated deployment thus it would be hard to test the inter-cell interference mitigation effect without a centralized Wi-Fi access controller (AC).

Considering that Wi-Fi is a TDD system, we chose TD-LTE small cell in the comparison of user experience test.

7.2.2 QoS Test of Typical Services

The user experience is tested for some typical services, including Ping latency, FTP downloading time and bitrate, online video playing. The tests results are summarized in the following section.

1) Ping latency

Ping latency in milliseconds with an application of uploading small data packet to a server. Different load scenarios are simulated with 0~4 concurrent FTP users.

Test method:

Send 32kB packet data to server, record ping latency under heavy load 1. scenario.

The heavy load scenario is such that concurrent FTP users are increased 2. one by one and one user sends a ping packet.

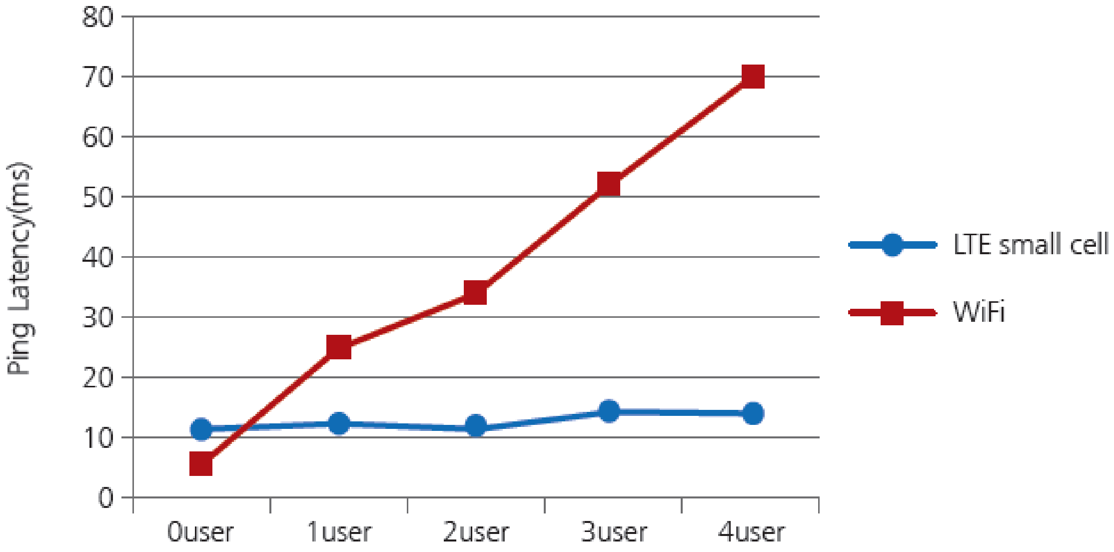

Figure7.1: Ping latency comparison between LTE small cell and Wi-Fi

Figure 7.1 shows that the ping latency of LTE remains stable around 10ms, while the ping latency of Wi-Fi increases dramatically, from 7ms to 70ms with increasing number of concurrent FTP users, due to the contention based resource competition scheme in Wi-Fi.

2) FTP downloading time

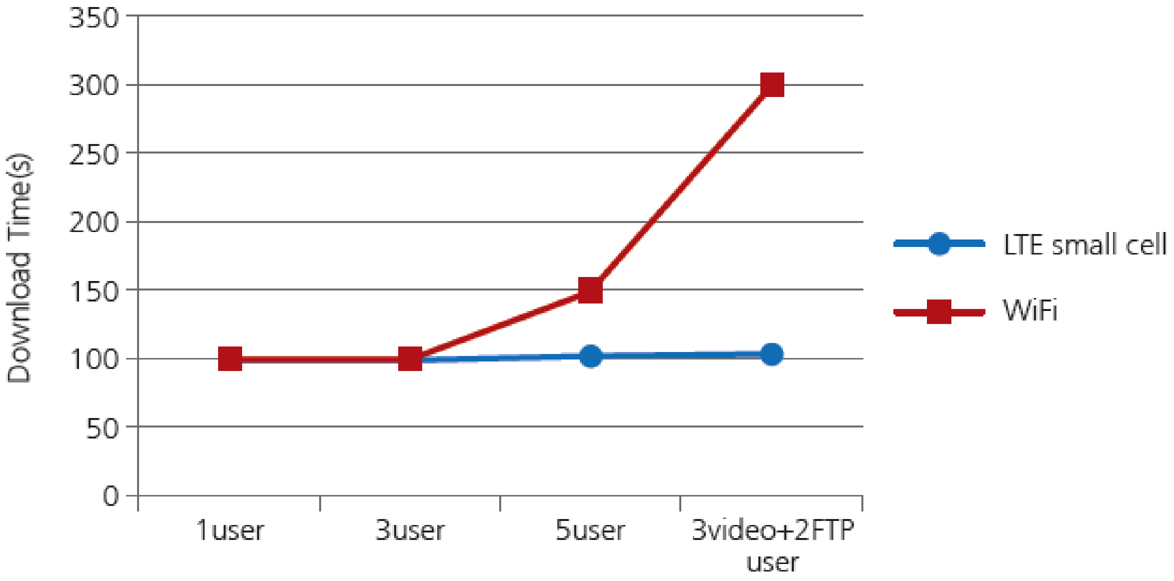

Figure7.2: FTP Downloading time comparison between LTE small cell and Wi-Fi

The FTP downloading time is tested in single user and multiple user scenarios, as shown in Figure7.2. It is observed that the FTP download time with LTE small cell is almost the same in multi-user and single user conditions. For Wi-Fi, however, the download time increases obviously when the total traffic load of the Wi-Fi AP reaches a certain level

3) Online Video Service

Online movie/video services are becoming more and more popular and will be the dominant services in the future mobile broad band (MBB) system. The quality of online video service is tested in a scenario with high traffic load in the same cell, with three video users and two FTP users accessing the cell simultaneously.

It is observed that under heavy load scenario with concurrent FTP and online video users accessing one cell simultaneously, the online video downloading bitrate of Wi-Fi is lower than that of LTE small cell, and also varies from time to time which leads to some interruption and discontinuity during the video playing period. With the same scenario, LTE small cell users have a much smoother online video experience.

The cell throughput of both LTE and Wi-Fi are tested for different user density scenarios, by recording every user FTP uplink and downlink bit rates for the single cell scenario with different numbers of active users, as shown in Figure 7.3.

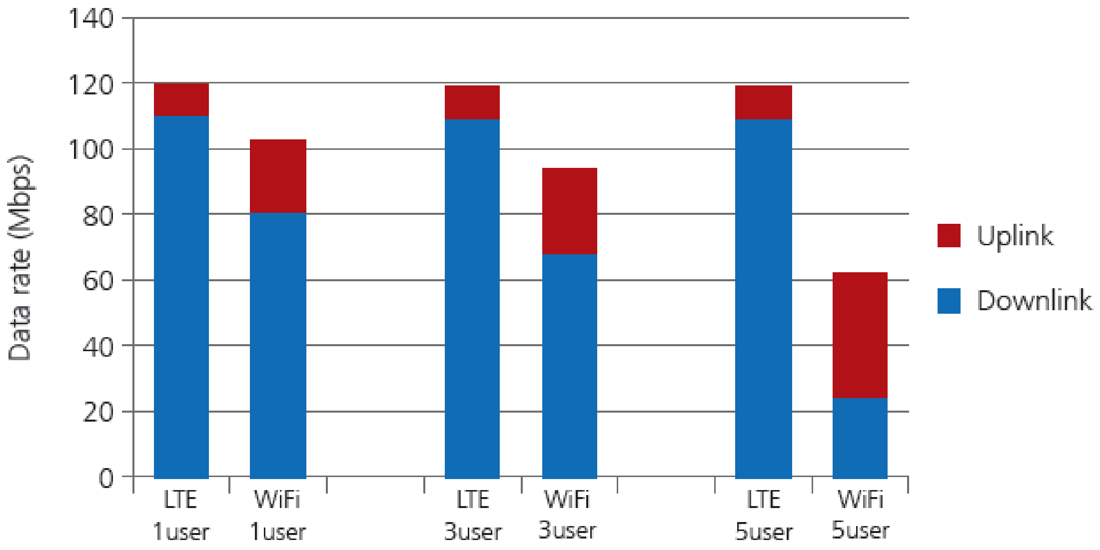

Figure7.3: FTP DL & UL throughput comparison between LTE small cell and Wi-Fi

It is observed that in order to support the same type of services, the LTE cell throughput in both downlink and uplink remains constant, independently of the number of served users. However, the downlink and uplink data rates of Wi-Fi decrease as the number of served users increases, leading to unpredictable downlink and uplink throughput per user.

7.3 Link-adaptation Mechanism Comparison

LTE and Wi-Fi have different link adaptation and retransmission mechanisms, according to the specifications:

1. LTE Rel-8: HARQ + turbo code, with modulation from QPSK to 64QAM
2. Wi-Fi IEEE802.11n: ARQ + convolution code, with modulation from QPSK to 64QAM

The relationship between the modulation and coding efficiency and SINR, for both LTE and Wi-Fi. It is observed that the modulation and coding efficiencies of LTE is better than Wi-Fi.

This is due to the fact that Wi-Fi does not have dynamic link adaptation, thus the scheduling efficiency varies a lot for different configurations. The potential modulation and coding efficiency with well-planned initial modulation and coding scheme selection with ideal channel quality estimation or with 1dB estimation error. Commercial Wi-Fi routers, however, have quite diverse configurations, thus some may have even worse efficiency.

It is worth noting that both IEEE 802.11ac and LTE Rel.12 introduce higher order-modulator up to 256QAM in downlink, which improve the peak modulation and coding efficiencies to 6.67bits/symbol (Wi-Fi) and 7.43bits/ symbol (LTE), respectively.

Summary

According to the above test and analyses, LTE Small Cell provides good performance with more efficient scheduling mechanism and better guaranteed QoS of typical services compared to Wi-Fi:

1. Ping latency of LTE Small Cell in multi-user scenario is almost the same as that in single-user scenario, while ping latency of Wi-Fi increases dramatically with increasing number of served users.

2. Under heavy load scenario, the FTP downloading time in Wi-Fi is quite high, and the online video playing is not very smooth with some interruptions. With the same loaded scenario, LTE Small Cell users can have a stable FTP downloading time and smoother online video experience.

3. The link adaptation mechanism of LTE small cell provides better link performance than Wi-Fi
4. Standard Evolution and Industrial Environment

7.4 Standard Evolution

7.4.1 Standard Evolution Roadmap of LTE Small Cell

LTE Small Cell keeps evolving in 3GPP, as shown in the LTE standard roadmap. The latest LTE Small Cell Enhancement (SCE) work items were setup in Rel-12, and are expected to be completed in June 2014.

7.4.2 Standard Evolution Roadmap of Wi-Fi

The IEEE802.11 series standard evolution, the core Wi-Fi functionality standard evolved to 802.11n and 802.11ac based on the requirement of wider bandwidth and higher data rate for local fixed access. There is an ongoing study on HEW (high-efficient WLAN) for the potential further enhancement. Considering the QoS enhancement and new service support (e.g. video transport stream), other 802.11 standard evolution branches are introduced, e.g. 802.11ae and 802.11aa.

7.4.3 Deployment Scenarios of LTE Small Cell

For LTE small cell deployment scenario, the main deployment scenario is in the cellular network deployed by a mobile network operator, where LTE small cell can provide the capacity enhancement and coverage extension for macro cell with the compatible QoS and the efficient coordinated resource management by taking the advantage of the close coupling between macro cell and small cell.

There are also scenarios with some hotspot and enterprise small cell coverage deployed by third party, where LTE small cell can also provide the high capacity for the coverage of the third party area with the limited access and authentication, guaranteed security and QoS. The small cell network can work in a standalone way without interworking with operators' macro cell.

Recently, the potential LTE small cell operation aggregating a supplemental carrier in unlicensed spectrum starts to attract some attention in the industry and is under discussion.

7.4.4 Deployment Scenarios of Wi-Fi

The main Wi-Fi deployment scenario is residential deployment, e.g. to provide the extension of wire line wideband for the local fixed access from home, which mainly contains one or few APs and STAs, low cost requirement, and with low QoS requirement.

In recent years, due to limited spectrum resources, some operators started to deploy Carrier Grade Wi-Fi (CGW) as a complement to their macro cellular network, for offloading cellular traffic in some hotspot areas. Generally the telecommunication level Wi-Fi AP is much more expensive than a residential AP, and also supports interworking with 2G/3G or 4G networks.

To provide a convenient access to internet, e.g. wireless city project, some third party or government may also deploy Wi-Fi access in hotspot areas, some of which adopt telecommunication level AP to support continuous coverage of the hotspot area and to permit access of more users than residential networks. However, it is still hard to guarantee the security and QoS.

7.5 Commercial Maturity Analysis

From the commercial scale point of view, both LTE and Wi-Fi are very successful. Both 3GPP and Wi-Fi alliance are paying attention to the interworking between Wi-Fi and cellular network as well, while some latest specification requires upgrade of terminal implementation and test. The industry chain of both LTE small cell and Wi-Fi are analyzed as follows.

Chipset and Terminal Maturity: LTE protocol phase I (LTE Rel-8) and Wi-Fi phase II (IEEE802.11n) already released a lot of commercial chipsets and terminals. LTE FDD and TDD specification are commonly defined, which makes it easy for chipset design and terminal implementation to support both modes.

Wi-Fi phase III (IEEE802.11ac) is in the roadmap of many vendors, similar as LTE small cell enhancement (e.g. Rel-11/12).

Candidate spectrum: LTE small cell may be deployed in the same spectrum as macro cells, and may also have some small cell specific spectrum. The first batch contains bands that are already assigned to LTE system, e.g. 2.3GHz and 2.6GHz. The second batch consists of potential small cell specific bands, e.g. 3.5GHz or spectrums with a bit higher frequency. There is discussion for potential application in the 5.8GHz band as well.

Wi-Fi residential spectrum is mainly in 2.4GHz, which is already very crowded. The second batch is around the 5GHz area. The third batch is 60GHz and some potential bands below 1GHz, e.g. TV white space

7.6 Conclusion

This provides the analysis of the small cell solutions based on both LTE and Wi-Fi, with a focus on the user experience test.

LTE Small Cell is suitable for the typical service application in the cellular network deployed by an operator or a large scale enterprise. With close coupling with the Macro layer, the operator can easily manage LTE Small Cell and control the user experience with the unified interface of the traditional LTE system, and support good mobility performance. The LTE air interface is well designed for supporting a substantial number users, guaranteed security and QoS in diverse deployment scenarios, and complex traffic situations.

Wi-Fi is most suitable for application in residential or small coverage deployment with a smaller number of users, such as the home, isolated hot spot or small scale enterprise. The contention based scheduling and network management of high user density scenario is the bottleneck for Wi-Fi. To improve its performance in the cellular scenario, higher cost is expected.

Chapter8

Automated Switching to Selected UE Mode of operation for Restricted Area in LTE

8.1Introduction

The way to disable the use of handset by using Signal Strength based (RSS) Handoff Mechanism is shown. Here, Dummy transmitting antenna is used to do it and there is no need of any external circuitry for the cell phone.

A working principle was proposed for mobile station inside the nuclear power plant. Though the method was based on CDMA network, it was also applicable for the other networks. To adjust the transmitting power to 0W, two additional sub-states were included in that methodology: static sub-state, deadlock sub-state. In static sub-state, the mobile station can receive data but the power of the mobile station is automatically adjusted to 0W. In deadlock sub-state, the transmitted and received power is adjusted to 0W and after sometimes the mobile station will again enter into system determination state.

Airplane mode is a setting on many cellphones which disables their wireless communication abilities, theoretically making them approved for use on aircraft.

There are two reasons why people are not allowed to use cell phones on aircraft, although the rules against cell phone usage may change at some point. The first reason is that the radio signals emitted by phones could interfere with the communications and guidance systems on the aircraft, which could potentially be very dangerous. In addition, cell phone networks on the ground cannot cope with cell phones being used on planes, because planes travel very fast and at high altitude, so a phone on a plane could confuse a network on the ground.

8.2Working method for the mobile station in the boot state

After booting, the mobile station will enter into the boot initialization state. In this state, the mobile station will continuously detect pilot signal and sync signal from the base station.

For the CDMA network, the mobile station initialization state can be divided into four sub-states:

- System determination sub-state;
- Pilot channel acquisition sub-state;
- Sync channel acquisition sub-state;
- Timing change sub-state.

The detail description of these four sub-states and the boot process will be omitted in this paper. In order to achieve the goal of automatically adjusting transmit power to 0W when the mobile station entering into the plant, two new sub-states will be increased. They are static sub-state and deadlock sub-state.

Static sub-state:

After capturing the pilot signal from a special base station, the mobile station will enter into this sub-state. At this point, the mobile station itself will automatically adjust transmit power to 0W, but can receive information from a special base station. Considering the security factor, the access standards of entering this state is quite broad: as long as the mobile station captures a special base station pilot signal, regardless of its strength, it will be always determined as successfully capture. Then the mobile station will immediately enter into static mode. For pilot signal from the normal base station, if captured signal strength is very low, which is below the threshold value, it will be determined as not capture.

Deadlock sub-state: When one mobile station does not capture either the pilot signal from special base station or that from normal base station, it will enter into this state. At this point, the mobile station will adjust transmit power and received power to 0W. After some time, the mobile station will re-enter into system determination sub-state.

The reason for adding this sub-state is as follows:

To distinguish it from the static sub-state.

If one mobile station does not capture any pilot signal, it is possible that the electromagnetic shielding is strong. It is very likely that the mobile station is in the area of industrial buildings. At this point, no signal will be allowed to transmit from the mobile station; another situation is hardware problems. If so, the mobile station is not allowed to transmit any signal because it may be in the industrial building.

8.3Aplication Model

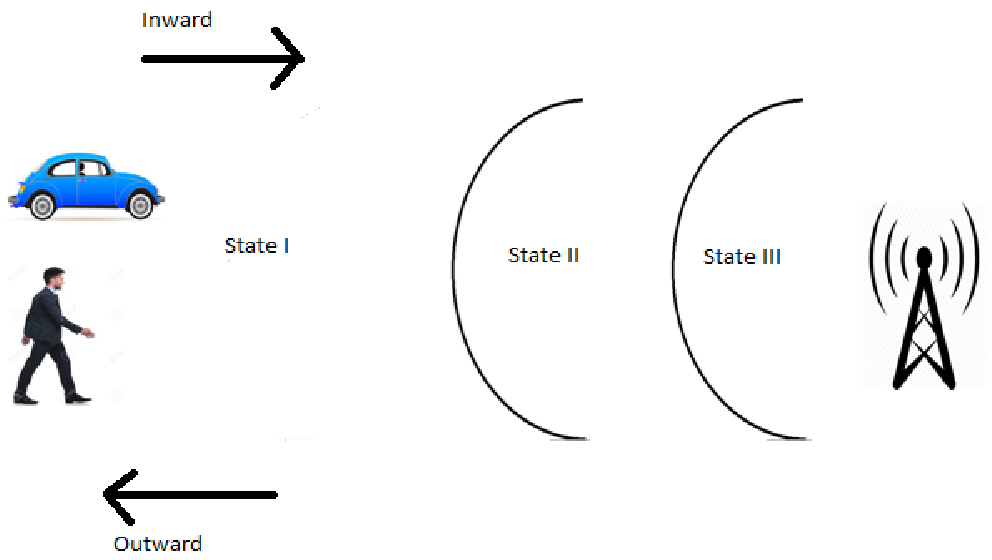

Figure 8.1: Application Model of Automated Switching

State	A (Mosque, Church, Library)	B (Nuclear power plant, Refinery plants)	C (Conference room, Class room, Parliament)	D (Airplane, Radiology unit of Hospital)
I	General mode	E mode	General mode	General mode
II	General mode	HA mode	Silent mode	E mode
III	Silent mode	HA mode	Silent mode	E mode

Table8.1 Different Modes of UE

General mode:

Transmitting Power Not Zero
Wi-Fi and Bluetooth ON
Sound ON

Silent mode:

- Transmitting Power Not Zero
- Wi-Fi and Bluetooth ON
- Sound OFF

Emergency (E) mode:

- Transmitting Power Zero
- Wi-Fi and Bluetooth ON
- Sound OFF

High Alert (HA) mode:

- Transmitting Power Not Zero
- Wi-Fi and Bluetooth OFF
- Sound OFF

8.4 SI Configuration

- There are two parts in System Information (SI): Master Information Block (MIB) and System Information Block (MIB).
- MIB describes Carries physical layer information of LTE cell which in turn help receive further SIs, i.e. system bandwidth.
- We have proposed here SIB-21. SIB-21 contains a indexed value (e.g. A,B,C,D) which indicates the scenario of cell surrounding.

8.5 Performance Analysis

The received power has been calculated using the following equation,

$$P_r = P_j G_j^k$$

$$G_j^k = 10^{(-PL_k + X_\alpha)/10}.\,|H_k|^2.$$

Where P_j is the transmit power of *j* cell,

G_j^k represents the channel gain of user *k* from *j* cell,

H is the Rayleigh fading,

X_α *is the* log-normal shadowing,

PL_k is the path losses.

For indoor case, we have considered

Rayleigh fading *H=1*,

log-normal shadowing $X_\alpha = 0$

For small cell: PL = 140.7 + 36.7 log10(d)

where d (in km) is the distance from cell

The typical cell radius of small cell is in between 10m to 50m [3]. We have considered here 50m.

Assuming Transmitted power, Pt= 200mW =23 dBm

Distance (m)	Path loss (dBm)	Pt (dBm)	Pr (dBm)	TTT (Time to trigger) (s)	RSRP value (dBm)	RSRP - Range IE Value
50	92.9522	23	-69.9419	3	-69<=RSRP<-70	71
40	89.3956		-66.3853	3	-66<=RSRP<-67	74
30	84.8104		-61.8001	3	-61<=RSRP<-62	79
20	78.3478		-55.3375	3	-55<=RSRP<-56	85
10	67.3000		-44.2897	3	-44<=RSRP<-45	96

	Inward Case	Outward Case
Actual Distance (m)	Threshold power (dBm)	Threshold power (dBm)
50	-68.5551	-71.2177
40	-64.6320	-67.9647
30	-59.4167	-63.8729
20	-51.6140	-58.3538
10	-35.6988	-49.8412

For distance 40m:

Speed (km/hr)	P (Inward)	P (Outward)	Ddiv_1	Ddiv_2
5	-67.9647	-64.6320	4.1667	4.1667
10	-69.4016	-62.6618	8.3333	8.3333
15	-70.7195	-60.4132	12.5000	12.5000
20	-71.9368	-57.7944	16.6667	16.6667
25	-73.0677	-54.6592	20.8333	20.8333
35	-75.1139	-45.5655	29.1667	29.1667

For distance 20 m:

Speed (km/hr)	P (Inward)	P (Outward)	Ddiv_1	Ddiv_2
5	-58.3538	-51.6140	4.1667	4.1667
10	-60.8890	-46.7466	8.3333	8.3333
15	-63.0758	-39.7044	12.5000	12.5000
20	-64.9985	-26.7793	16.6667	16.6667
25	-66.7139	-4.6837 + 4.5024i	20.8333	20.8333
35	-69.6740	-42.9029 + 4.5024i	29.1667	29.1667

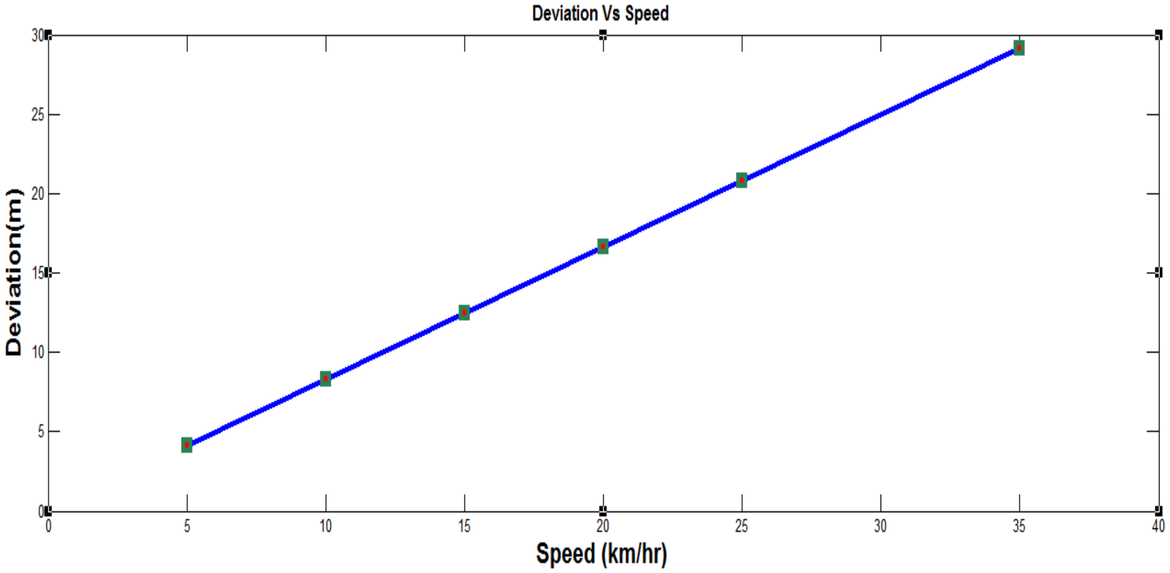

Figure8.2: Deviation vs Speed Curve

8.6 Conclusion

Though our model is proposed for LTE, it can be supported for any high speed network. This model is safe and reliable for most of the sensitive and restricted areas.

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