PERFORMANCE OPTIMIZATION OF WIRELESS SENSOR NETWORKS: IN CONVERGENCE WITH MOBILE CELLULAR NETWORKS

A PROJECT REPORT

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BONAFIDE CERTIFICATE

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ABSTRACT

Machine-to-machine (M2M) communications are strongly application-oriented, and have been widely used in many areas. As they are highly related to the particular market scenarios and have various optimization targets, different M2M communications may need different technologies. Nowadays, the necessity for M2M communications is to meet the fast-increasing requirements of data centric wireless services and applications without the direct interactions with human beings. However, generally the terminals in M2M communications have less mobility. Mobile cellular networks (MCN) and wireless sensor networks (WSN) are evolving from heterogeneous networks to converged networks, in order to support M2M communications. This work investigates and discusses key technical challenges and optimization for the convergence of MCN and WSN. It has been proposed that the mobile terminals in MCN act as both sensor nodes and gateways for WSN in the converged networks. This work aims to improve the system performance using the interactive optimization with MCN and enhancing the QoS parameters by implementing optimal hand-off and interference avoidance techniques, in terms of throughput, delay and network lifetime.

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LIST OF ABBREVIATIONS

WSN	Wireless Sensor Network
M2M	Machine to Machine
MCN	Mobile Cellular Network
QoS	Quality of Service
WLAN	Wireless Local Area Network
BS	Base Station
MAC	Media Access Control
PHY	Physical Layer
MEMS	Micro Electro Mechanical System
PAN	Personal Area Network
UWB	Ultra Wide Band
IoT	Internet of Things
WLAN	Wireless Local Area Network
QoS	Quality of Service
CDMA	Code Division Multiple Access
MC-CDMA	Multi-Carrier Code Division Multiple Access
TDMA	Time Division Multiple Access
FDMA	Frequency Division Multiple Access
PDMA	Polarization Division Multiple Access
UE	User Equipment
AODV	Ad hoc On-demand Distance Vector
ICI	Inter Cell Interference
OFDM	Orthogonal Frequency Division Multiplexing

OFDMA	Orthogonal Frequency Division Multiple Access
MIMO	Multiple Input Multiple Output
CRC	Cyclic Redundancy Check
SNR	Signal to Noise Ratio
SIR	Signal to Interference Ratio
GPS	Global Positioning System
SSAS	Simplified sub channel allocation scheme
OSAS	Optimal sub channel allocation scheme
SFR	Soft Frequency Reuse
PFR	Partial Frequency Reuse
PDR	Packet Delivery Ratio
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
ATM	Asynchronous Transfer Mode
NS2	Network Simulator 2

CHAPTER 1

INTRODUCTION

1.1 WIRELESS SENSOR NETWORK

A Wireless Sensor Network (WSN) is a self-configuring network of small sensor nodes communicating among themselves using radio signals, and deployed in quantity to sense, monitor and understand the physical world. It consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location.

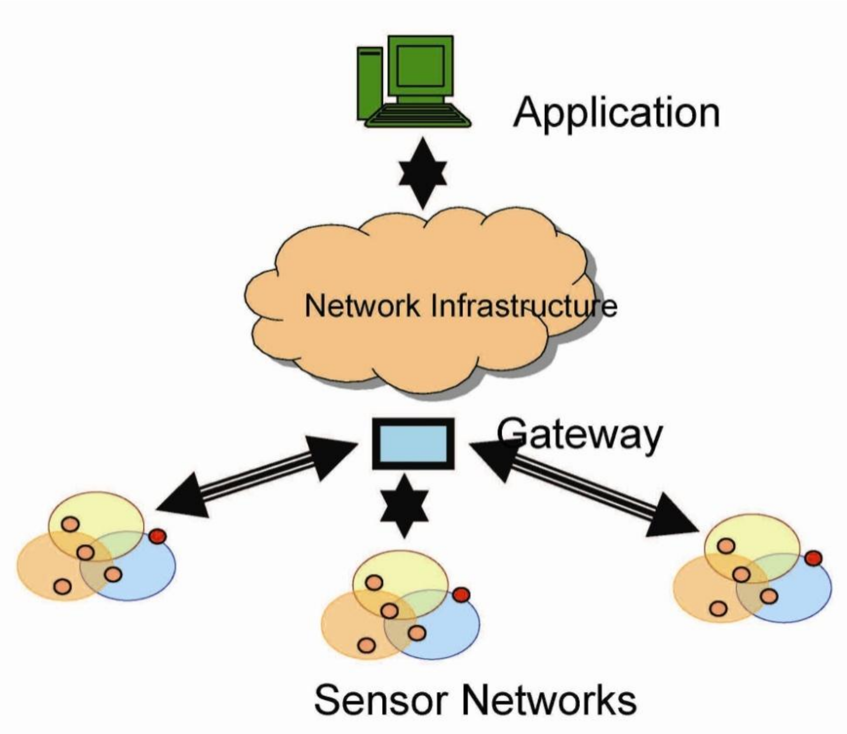

Fig.1.1 WSN Architecture

The more modern networks are bi-directional, enabling also to control the activity of the sensors. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring and so on.

Multiple sensors (often hundreds or thousands) form a network to cooperatively monitor large or complex physical environments. Acquired information is wirelessly communicated to a base station (BS), which propagates the information to remote devices for storage, analysis, and processing.

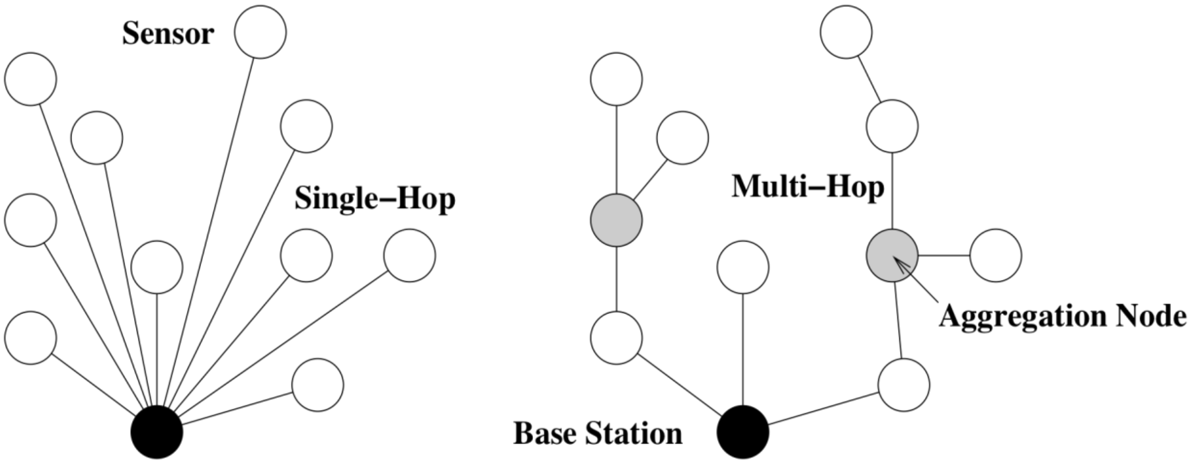

Fig.1.2 Single-Hop and Multi-Hop Transmission

Every sensor communicates directly with the base station. It may require large transmit powers and may be infeasible in large geographic areas. This is called as single hop transmission. A sensor, which serve as relay for other sensor nodes to transmit the data is called Multi-hop transmission. It may reduce power consumption and allows for larger coverage. It introduces the problem of routing.

1.1.1 SENSOR NODE

The WSN is built of "nodes" - from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting.

A wireless sensor node is composed of four basic components as shown in fig..3: a sensing unit, a processing unit (microcontroller), a transceiver unit and a power unit.

In addition to the above units, a wireless sensor node may include a number of application-specific components, for example a location detection system or mobiliser; for this reason, many commercial sensor node products include expansion slots and support serial wired communication.

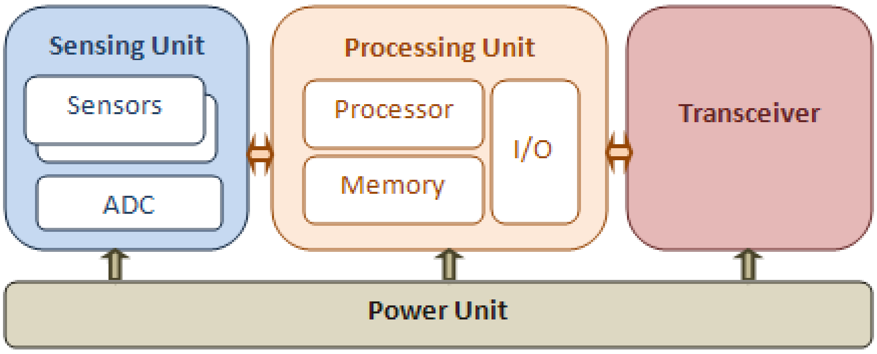

Fig.1.3 Components of Sensor Node

Sensing Unit: The main functionality of the sensing unit is to sense or measure physical data from the target area. The analog voltage or signal is generated by the sensor corresponding to the observed phenomenon. The continual waveform is digitized by an analog-to-digital converter and then delivered to the processing unit for further analysis. The sensing unit is a current technology bottleneck because the sensing technologies are much slower than those of the semi-conductors.

Processing Unit: The processing unit which is generally associated with a small storage unit manages the procedures that make the sensor nodes collaborate with the other nodes to carry out the assigned sensing tasks.

Transceiver: There are three deploying communication schemes in sensors including optical communication (laser), infrared, and radio-frequency. Laser consumes less energy than radio and provides high security, but requires line of sight and is sensitive to atmospheric conditions. Infrared, like laser, needs no antenna but is limited in its broadcasting capacity. RF is the most easy to use but requires antenna.

Various energy consumption reduction strategies have been developed such as modulation, filtering, and demodulation. Amplitude and frequency modulation are standard mechanisms. Amplitude modulation is simple but susceptible to noise.

Power Unit: One of the most important components of a sensor node is the power unit. Every sensor node is equipped with a battery that supplies power to remain in active mode. Power consumption is a major weakness of sensor networks. Any energy preservation schemes can help to extend sensor's lifetime. Batteries used in sensors can be categorized into two groups; rechargeable and non-rechargeable. Often in harsh environments, it is impossible to recharge or change a battery.

1.1.2 CHARACTERISTICS

The main characteristics of a WSN include:

- Power consumption constrains for nodes using batteries or energy harvesting
- Ability to cope with node failures
- Mobility of nodes
- Communication failures
- Scalability to large scale of deployment
- Ability to withstand harsh environmental conditions
- Ease of use

Sensor nodes can be imagined as small computers, extremely basic in terms of their interfaces and their components. They usually consist of a processing unit with limited computational power and limited memory, sensors or MEMS (including specific conditioning circuitry), a communication device (usually radio transceivers or alternatively optical), and a power source usually in the form of a battery.

The base stations are one or more components of the WSN with much more computational, energy and communication resources. They act as a gateway between sensor nodes and the end user as they typically forward data from the WSN on to a server. Other special components in routing based networks are routers, designed to compute, calculate and distribute the routing tables.

1.1.3 WSN COMMUNICATIONS TECHNOLOGY REQUIREMENTS

Since WSNs tend to have a larger variety of applications, different communications technologies can be used for WSN, such as WiFi, Bluetooth, UWB and Zigbee. Since IEEE 802.11 technology lacks a low-power mode, it is not suitable for the low-powered and highly integrated WSN. The IEEE 802.15 working group provides standards for low-complexity and low-power consumption wireless connectivity at physical (PHY) and media access control (MAC) layers.

Table 1 shows some figures about the WSN system parameters such as the delay and throughput by using the different wireless technologies.

Feature	**WiFi (IEEE 802.11x)**	**Bluetooth (IEEE 802.15.1)**	**UWB (IEEE 802.15.3)**	**ZigBee (IEEE 802.15.4)**
Range	<100m	<10m	<10m	10-100m
Data rate	11a < 54 Mb/s 11b < 11 Mb/s 11g < 54 Mb/s	1-3Mbps	480 Mbps with impulsive radio	20, 40 and 250 kbps
Operating frequency	11b/g: 2.4GHz, 11a: 5GHz	2.4 GHz	3.1-10.6 GHz	868 MHz, 915 MHz, 2.4 GHz
Network Size (nodes)	Few, depends on interference and achieved data rate	2 up to 8 per piconet	2	<65536
Scalability	No	No	-	Yes
Battery life	Hours or access points connecting with power supply	a week	a week	>1 year
Data type	Video, audio, graphics, pictures, files	Audio, graphics, pictures, files	Video, audio, graphics, pictures, files	Small data packet
New slave connect	Up to 3 s	Up to 10 s	-	30 ms

Table 1.1 Characteristics of WSN communications technologies

WiFi is mainly used for high data rate transmission in wireless internet connection. WiFi technology allows different devices like laptops, personal computers (PCs), cell phones, and personal digital assistants (PDAs) to communicate between one another or to connect to the Internet without needing a cable connection. There are different standard versions known as IEEE 802.11x (a, b, or g), which are available in one chip. WiFi network protocols are operating in the unlicensed radio bands of 2.4GHz and 5GHz. WiFi certified device can operate with data rates of 11Mbps for IEEE 802.11b or 54 Mbps for IEEE 802.11a. The greater the distance to the access point, the lower the performance. However, WiFi technology lacks a low-power mode, and its lifetime cannot be very long without the power supply. Thus, a low-powered WSN cannot use this technology.

Bluetooth technology has a low-power mode and operates in the unlicensed 2.4GHz band, which is a suitable choice for convenient, wire-free, short-range communications between devices. The Bluetooth wireless communications technology provides a personal area network (PAN) for exchanging data between Bluetooth-capable devices within certain proximity. The main objective of Bluetooth was to replace the wired connections between personal devices (such as mobile phone, digital camera, etc), which can deliver relatively high data rate (about 1 Mb/s - 3 Mb/s). But the Bluetooth networking capabilities are not strong enough for large networks and it is limited to short-distance communications. For this reason, Bluetooth is just mentioned and described as an existing technology for developing WSN.

The Ultra Wideband (UWB) technology allows information to be transmitted at a large bandwidth in precise pulses that are typically 1 to 2 nanoseconds in length and occupy at least 25% of the center frequency, much more than other systems. UWB is a proposed as a solution for huge data rate transmission in very short distances (<10 meters). The data rate can be as high as 480 Mb/s or even much more. The use of this technology is limited to the frequencies range from 3.1 to 10.6 GHz. Its remarkable characteristic is its better interference than other technologies, nevertheless, UWB transmission range is limited. Besides the transmission distance, the frequency (3.1-10.6GHz) is another main reason for not going into normal WSN research.

ZigBee is established by the ZigBee Alliance, which added flexible network, security and application protocol to IEEE 802.15.4 standard. The Zigbee transmission range is expected to be up to about 100 m. ZigBee can operate in unlicensed bands, such as 868 MHz, 915 MHz and 2.4GHz, with transmission rates of 20, 40 and 250 kbps. These are relatively low rates compared to the WiFi and Bluetooth protocols, but they are adequate for their service applications in the M2M sensing process. The ZigBee technology is a communications standard for systems with requirements such as long battery life, low data rates, secure communications, and less complexity compared with previous wireless standards. Owing to its low power consumption and simple networking configuration, ZigBee is considered the most promising for WSN.

1.1.4 DESIGN CHALLENGES

1. **Power Consumption-** Wireless sensor node is microelectronic device means it is equipped with a limited number of power source. Nodes are dependent on battery for their power. Hence power conservation and power management is an important issue in wireless sensor network.

2. **Short Range Transmission-** In WSNs we should consider the short transmission range in order to reduce the possibility of being eavesdropped.

3. **Scalable and flexible architecture-** the network must preserve its stability. Introducing more nodes into the network means that additional communication messages will be exchanged, so that these nodes are integrated into the existing network.

4. **Node Deployment-** Sensor network can be deployed randomly in geographical area. After deployment, they can be maintained automatically without human presence.

5. **Limited computational power and memory size-** It is another factor that affects WSN in the sense that each node stores the data individually and sometime more than one node stored same data and transferred to the base station which waste the power and storing capacity of nodes so we must develop effective routing schemes and protocols to minimize the redundancy in the network.

1.1.5 DATA COLLECTION

The sensing data are collected at sensor nodes and forwarded to a sink for further processing is called Data Collection in Wireless Sensor Networks. It is used to periodically extract the sensor readings. Data collection can be broadly classified into event based and periodic data collection.

A large number of sensors are scattered over a field and extract data of interest by reading the real-world phenomena from the physical environment. Since sensors are typically battery-powered and left unattended after the initial deployment, it is generally infeasible to replenish the power supplies once they deplete the energy. Thus, energy consumption becomes a primary concern in a WSN, as it is crucial for the network.

A major portion of energy expenditure in WSNs is attributed to the activities of aggregating data to the data sink. Energy saving is an issue in data aggregation in WSNs. In some schemes, data packets are forwarded to the data sink via multi-hop relays among sensors. Some issues like schedule pattern, load balance and data redundancy were also jointly considered along with routing to further improve energy efficiency.

In multi-hop routing, packets have to experience multiple relays before reaching the data sink. As a result, much more energy is consumed on data forwarding along the path. Moreover, minimizing energy consumption on the forwarding path does not necessarily prolong network lifetime as some popular sensors on the path may run out of energy faster than others, which may cause non-uniform energy consumption across the network.

Mobile data gathering is a technique, which employs one or more mobile collectors that are robots or vehicles equipped with powerful transceivers and batteries. A mobile collector roams over a sensing field, "transports" data while moving, or pauses at some anchor points on its moving path to collect data from sensors via short range communication. In this way, energy consumption at sensors can be greatly reduced, since the mobility of the collector effectively dampens the relay hops of each packet.

To pursue the maximum energy saving, the mobile collector should traverse the transmission range of each sensor in the field so that each packet can be transmitted to the mobile collector in a single hop. Due to the low velocity of the mobile collector, it would incur long latency in data gathering, which may not meet the delay requirements of time-sensitive applications.

The latency of multi hop relay routing and its variants is much shorter than that of the mobile data gathering. The mobile data gathering pursues energy saving by simply reducing the relay hops among sensors. To overcome the above problems, there must be an intrinsic trade off between the energy saving and the data gathering latency.

1.2 CELLULAR NETWORK

A cellular network is a wireless network distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a cell site or base station. In a cellular network, each cell uses a different set of frequencies from neighbouring cells, to avoid interference and provide guaranteed bandwidth within each cell.

When joined together these cells provide radio coverage over a wide geographic area. This enables a large number of portable transceivers (e.g., mobile phones, pagers, etc.) to communicate with each other and with fixed transceivers and telephones anywhere in the network, via base stations, even if some of the transceivers are moving through more than one cell during transmission.

Cellular networks offer a number of desirable features:

- More capacity than a single large transmitter, since the same frequency can be used for multiple links as long as they are in different cells.
- Mobile devices use less power than with a single transmitter or satellite since the cell towers are closer.
- Larger coverage area than a single terrestrial transmitter, since additional cell towers can be added indefinitely and are not limited by the horizon

Major telecommunications providers have deployed voice and data cellular networks over most of the inhabited land area of the Earth. This allows mobile phones and mobile computing devices to be connected to the public switched telephone network and public Internet.

The most common example of a cellular network is a mobile phone network. A mobile phone is a portable telephone which receives or makes calls through a cell site called base station, or transmitting tower. Radio waves are used to transfer signals to and from the cell phone. Modern mobile phone networks use cells because radio frequencies are a limited, shared resource. Cell-sites and handsets change frequency under computer control and use low power transmitters so that the usually limited number of radio frequencies can be simultaneously used by many callers with less interference.

A cellular network is used by the mobile phone operator to achieve both coverage and capacity for their subscribers. Large geographic areas are split into smaller cells to avoid line-of-sight signal loss and to support a large number of active phones in that area. All of the cell sites are connected to telephone exchanges (or switches), which in turn connect to the public telephone network.

- An example of a simple non-telephone cellular system is an old taxi driver's radio system where the taxi company has several transmitters based around a city that can communicate directly with each taxi.

In a cellular radio system, a land area to be supplied with radio service is divided into regular shaped cells, which can be hexagonal, square, circular or some other irregular shapes, although hexagonal cells are conventional. Each of these cells is assigned multiple frequencies (f_1 - f_6) which have corresponding radio base stations. The group of frequencies can be reused in other cells, provided that the same frequencies are not reused in adjacent neighboring cells as that would cause co-channel interference. The increased capacity in a cellular network, compared with a network with a single transmitter, comes from the fact that the same radio frequency can be reused in a different area for a completely different transmission. If there is a single plain transmitter, only one transmission can be used on any given frequency. Unfortunately, there is inevitably some level of interference from the signal from the other cells which use the same frequency. This means that, in a standard FDMA system, there must be at least a one cell gap between cells which reuse the same frequency. In the simple case of the taxi company, each radio had a manually operated channel selector knob to tune to different frequencies. As the drivers moved around, they would change from channel to channel. The drivers know which frequency covers approximately what area. When they do not receive a signal from the transmitter, they will try other channels until they find one that works. The taxi drivers only speak one at a time, when invited by the base station operator (in a sense TDMA).

1.2.1 CELL SIGNAL ENCODING

To distinguish signals from several different transmitters, frequency division multiple access (FDMA) and code division multiple access (CDMA) were developed. With FDMA, the transmitting and receiving frequencies used in each cell are different from the frequencies used in each neighboring cell. In a simple taxi system, the taxi driver manually tuned to a frequency of a chosen cell to obtain a strong signal and to avoid interference from signals from other cells. The principle of CDMA is more complex, but achieves the same result; the distributed transceivers can select one cell and listen to it. Other available methods of multiplexing such as polarization division multiple access (PDMA) and time division multiple access (TDMA) cannot be used to separate signals from one cell to the next since the effects of both vary with position and this would make signal separation practically impossible. Time division multiple access, however, is used in combination with either FDMA or CDMA in a number of systems to give multiple channels within the coverage area of a single cell

1.2.2 MOVEMENT FROM CELL TO CELL AND HANDOVER

In a primitive taxi system, when the taxi moved away from a first tower and closer to a second tower, the taxi driver manually switched from one frequency to another as needed. If a communication was interrupted due to a loss of a signal, the taxi driver asked the base station operator to repeat the message on a different frequency. In a cellular system, as the distributed mobile transceivers move from cell to cell during an ongoing continuous communication, switching from one cell frequency to a different cell frequency is done electronically without interruption and without a base station operator or manual switching. This is called the handover or handoff. Typically, a new channel is automatically selected for the mobile unit on the new base station which will serve it. The mobile unit then automatically switches from the current channel to the new channel and communication continues. The exact detail of the mobile system's move from one base station to the other varies considerably from system to system.

1.2.3 CONVERGENCE OF WSN AND MCN

Machine-to-machine communications are emerging as new communication types different from the conventional human-to-human communications. M2M communications are strongly application-oriented, and have been widely used in many areas, such as healthcare and environmental surveillance. As they are highly related to the particular market scenarios and have various optimization targets, different M2M communications may need different technologies. However, generally the terminals in M2M communications have less mobility. Moreover, in certain cases, some terminals can be more powerful by installing multiple Tx/Rx antennas when they are stationary or slowly moving within a fixed area and not limited to size.

M2M communications can be realized separately within various wireless networks, such as mobile cellular networks (MCN), wireless local area networks (WLAN), and wireless sensor networks (WSN). For MCN, the 3GPP is drafting the standards covering machine-type communications for UMTS and LTE systems. Moreover, M2M communications using WLAN as a backhaul have been applied in intelligent residential villages/buildings and automatic assembly lines. The concept of the Internet of Things (IoT), which originated from WSN, is becoming more popular.

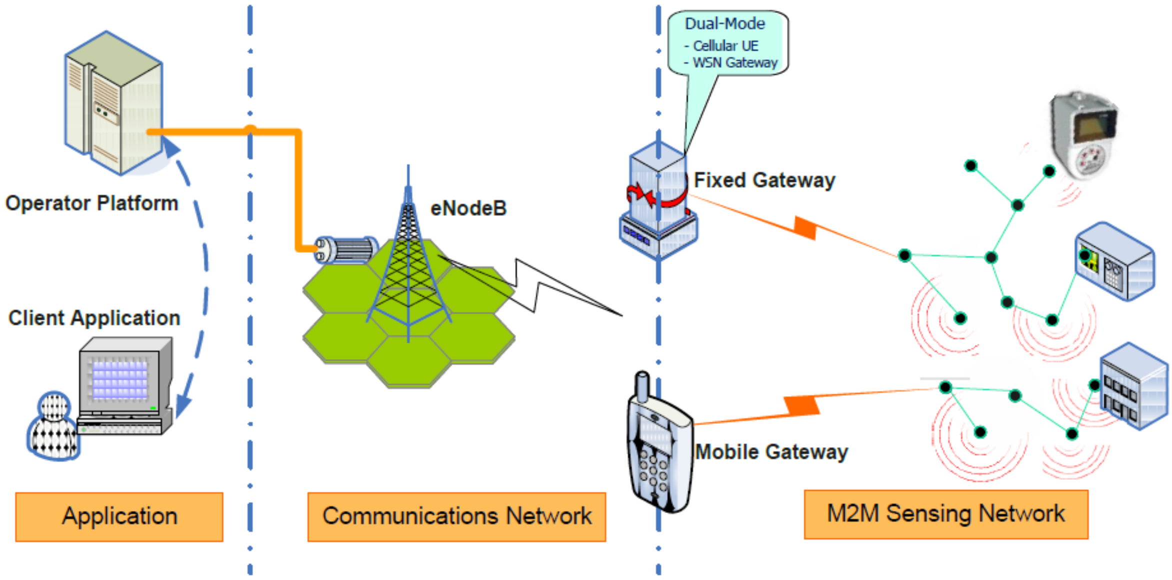

Fig.1.4 M2M System Architecture

WSNs can be flexibly deployed to support various smart applications. They have some key disadvantages, but are turned playing as the advantages in MCN. Therefore, it is intuitive to integrate MCN and WSN for supporting M2M communications. Heterogeneous networks consisting of MCN and WSN appear in many application areas. We believe joint optimization in heterogeneous networks can effectively improve system performance.

By proposing an interference avoidance algorithm in the converged network scenario, enhancement in Quality of Service parameters for both the networks can be achieved and thus is the focus of this work

CHAPTER 2

LITERATURE SURVEY

Fayu Li and Lazaros F. Merakos (1994) [3] This research proposes and evaluates a multi access protocol for integrating data traffic in the E(enhanced)-TDMA voice system with digital speech interpolation, which is an enhancement of the emerging North American digital cellular standard. The proposed protocol combines random access with slot reservation mechanisms to statistically multiplex data packets with speech spurt packets over the shared terminal-to-base air channel. The integrated protocol requires no modification in the voice access protocol used in the E-TDMA system, and can attain performance close to that of an ideal voice/data multiplexer. Furthermore, the protocol may enable multi slot assignment per TDMA frame to match the throughput needs of individual data terminals, and can accommodate application-dependent data transmission priorities. The protocol uses a combination of random access and slot reservation mechanisms, which complement each other and provide for adequate adaptivity to changing traffic loads. The obtained performance results show that the protocol can fully utilize the available channel capacity and keep the data throughput-delay performance "close" to that of an ideal voice/data multiplexer.

Furthermore, by treating voice slot assignments with preemptive priority over data, data traffic becomes transparent to voice terminals. The proposed protocol can accommodate multi slot assignments per frame to match the throughput needs of individual DT’s, as well as application-dependent data transmission priorities. Since no modification is required in the voice access protocol, the proposed protocol offers the potential of a low cost and high performance solution to the integration of data services in the planned digital cellular systems.

Wonjong Thee and John M. Cioffi (2000) [14] Initially the problem of increasing the capacity of multiuser OFDM system can be done by using the dynamic subchannel allocation technique. The assumptions are that the channel model is quasi-static and that the base station has perfect channel information. In traditional TDMA or FDMA systems, resource allocation for each user is non adaptively fixed, and the water-filling power spectrum is known to be optimal. Since the sub channel allocations among the users are not optimized, a group of users is likely to suffer from poor channel gains resulting from large path loss and random fading. To resolve this problem we derive a multiuser convex optimization problem to find the optimal allocation of sub channels, and propose a low-complexity adaptive sub channel allocation algorithm. Simulation results show that the proposed algorithm performs almost as well as the optimal solution. Also, higher spectral efficiency is achieved for larger number of users in a cell due to the multiuser diversity. We assume frequency selective quasistatic channels where channels do not vary within a block of transmission. Zero delay constraint, total power constraints, and independent uniform distribution of user location are assumed. Larger capacity can be found for relaxed delay constraint as more dimensions can be adaptively assigned. We show an optimal and propose a suboptimal subchannel allocation algorithm for a multiuser OFDM downlink. Similar work can be done for uplink, but different power constraints need to be considered. Although only one total power constraint at base station exists for downlink, multiple total power constraints exist for uplink depending on number of users. Since we assume static channel within a block of transmission, only frequency dimensions need to be assigned adaptively. By adaptively assigning frequency subchannels, we can take advantage of channel diversity among users in different locations, which we call *Multiuser di*versity. This multiuser diversity stems from channel diversity including independent path loss and fading of users

Chang R Y, Zhifeng Tao, Jinyun Zhang and C C. Jay Kuo (2000) [2] A novel practical low-complexity multicell orthogonal frequency-division multiple access (OFDMA) downlink channel-assignment method that uses a graphic framework is proposed in this paper. Our solution consists of two phases:

1) A coarse-scale inter-cell interference (ICI) management scheme and
2) A fine-scale channel-aware resource-allocation scheme. In the first phase, state-of-the-art ICI management techniques such as ICI coordination (ICIC) and base-station cooperation (BSC) are incorporated

In our framework particular, the ICI information is acquired through inference from the diversity set of mobile stations and is presented by an interference graph. Then, ICIC or BSC is mapped to the MAX k-CUT problem in graph theory and is solved in the first phase. In the second phase, channel assignment is accomplished by taking instantaneous channel conditions into account. Heuristic algorithms are proposed to efficiently solve both phases of the problem. Extensive simulation is conducted for various practical scenarios to demonstrate the superior performance of the proposed solution compared with the conventional OFDMA allocation scheme. The proposed scheme can be used in next-generation cellular systems such as the 3GPP Long-Term Evolution and IEEE 802.16m.

Proposed a two-level resource-allocation scheme where the radio network controller coordinates multiple cells in the first level and performs per-cell optimization in the second level. The first level is conducted based on perfect and predetermined knowledge of the SINR for all MSs on all subchannels. heuristic algorithms for their formulated problems based on SINR, with some quality-of-service (QoS) consideration and centralized and a distributed method for multicell OFDMA resource allocation based on the measurement of ICI. Note that one key assumption in this category of research is the availability of SINR. This assumption may be difficult to obtain a priori, however, because the interference depends on the distance, location, and occupied channel status of interferers, which are unknown before resource allocation. In other words, it is the mutual dependency of ICI that complicates the problem. Thus, a multicell resource allocation scheme that is contingent upon global and perfect knowledge of SINR may not be practical. The second category of work aims at developing systematic RRM techniques and policies as guidelines for resource allocation.

To mitigate formidable ICI and improve the overall system performance, similar RRM mechanisms were suggested for the multicell scenario in the 3GPP recently; new improvements have also been proposed in 3GPP standardization activities. Some of the ICIC schemes were designed based on the concept of soft reuse, i.e., asymmetric reuse factors are applied to cell-center and cell-edge regions. In particular, cell center is allowed to use a smaller reuse factor to enhance the spectral efficiency, because cell-center MSs, with reduced transceiving power, will cause less interference to neighbours, i.e., downlink power control (PC). A two-phase approach with coarse-scale ICI management and fine-scale channel aware allocation has been presented. In particular, the main task of managing the performance-limiting ICI in cellular networks was accomplished by a graphic approach in which state-of-the-art ICI management schemes such as ICIC and BSC can easily be incorporated. A separate handling of interference management and network capacity maximization in the proposed graph framework can deliver a substantial SINR performance improvement, which was confirmed by extensive computer simulation

Sternad M, Ottosson T, Ahlen A, Svensson A (2003) [12] A downlink radio interface is proposed for cellular packet data systems with wide area coverage and high spectral efficiency. A slotted OFDM radio interface is used, in which time frequency bins are allocated adaptively to different users within a downlink beam, based on their channel quality. Fading channels generated by vehicular 100 km/h users may be accommodated. Frequency division duplex (FDD) is assumed, which requires channel prediction in the terminals and feedback of that information to a packet scheduler at the base station. To attain both high spectral efficiency and good coverage within sectors/beams, a scheme based on coordinated scheduling between sectors of the same site, and the employment of frequency reuse factor above 1 only in outer parts of the sector, is proposed and evaluated. The resulting sector throughput increases with the number of active users. When terminals have one antenna and channels is Rayleigh fading. The main design principle here is instead to utilize channel state information to adapt the signaling, and use coding only sparingly. Several tools may be used for this purpose:

- Fast link adaptation can adjust the transmission rate to channels that vary in time due to short-term fading. This requires channel prediction and also interference suppression, to enable the use of high data rates. In a wide-band system, the fading will differ at different sub frequencies. This provides another dimension over which to perform resource allocation/scheduling, and suggests the use of an OFDM transmission scheme.
- Multiple transmit antennas in each sector and multiple antennas at mobile terminals can be used to suppress interference, increase the transmission range, or to improve the throughput by MIMO spatial multiplexing.
- Channels to different users will fade independently. With many active users, the channel could almost always be allocated to users who encounter favorable conditions.

The spectral efficiency will then increase with the number of active users; an effect sometimes denoted multiuser diversity. Its exploitation requires prediction of channel variations. It also requires appropriate scheduling algorithms to distribute resources among users .We here restrict the attention to downlinks, assuming an uplink of similar capacity and design to be available. The discussion is restricted to a base station infrastructure, with sectored antennas. The sectors or beams constitute cells. They may either be conventional (fixed), or their beam widths and angles may be slowly adjusted adaptively, based on the traffic requirements. There are K active users within a sector (cell) who have L receiver antenna branches each. Transmitters are in this paper assumed to have only one diversity branch per sector. This case serves as a baseline against which we at present compare various MIMO solutions. Furthermore, we assume different frequency bands for the uplink and the downlink. This avoids the severe synchronization problems of time division duplex solutions but requires a considerable amount of channel state information to be transmitted from mobiles to the scheduler. We consider the setting with simultaneous wide area coverage high vehicle speeds and FDD partly because it is difficult.

Methods that work well in this situation will probably work also for simpler scenarios. We here restrict the attention to downlinks, assuming an uplink of similar capacity and design to be available. The discussion is restricted to a base station infrastructure, with sectored antennas. The sectors or beams constitute cells. They may either be conventional (fixed), or their beam widths and angles may be slowly adjusted adaptively, based on the traffic requirements. There are K active users within a sector (cell) who have L receiver antenna branches each. Transmitters are in this paper assumed to have only one diversity branch per sector. This case serves as a baseline against which we at present compare various MIMO solutions. Furthermore, we assume different frequency bands for the uplink and the downlink. This avoids the severe synchronization problems of time division duplex solutions but requires a considerable amount of channel state information to be transmitted from mobiles to the scheduler.

We consider the setting with simultaneous wide area coverage high vehicle speeds and FDD partly because it is difficult. Methods that work well in this situation will probably work also for simpler scenarios. CRC checksum is used to detect erroneously received link-level packets and link-level retransmission is then performed. The maximum number of retransmission attempts depends on the delay sensitivity of the traffic class. The minimum retransmission delay, mT, is short. This reduces undesired effects on TCP flow control mechanisms

Rayleigh fading is now added to the path loss model and MRC with L antennas is assumed in the terminals. The average of the spectral efficiency over the sector area is then evaluated assuming the adaptive OFDM downlink with the adaptive modulation rate region boundaries of The coverage and spectral efficiency will depend crucially on the assumed scheduling strategy probability that a user is allocated a bin is made *independent of the absolute average SIR*, and is thus independent of the position within the sector. For Rayleigh fading, a scheduler that selects the terminal with the best SIR *relative* to its own average SIR, measured on a dB scale, maximizes the spectral efficiency under this constraint of position-independent access to time-frequency resources.

Niyato D, Hossain E (2006) [11] This scheme introduces a semi-analytical methodology for radio link level performance analysis in a multirate “orthogonal frequency-division multiple-access” (OFDMA) network with adaptive fair rate allocation. Multirate transmission is assumed to be achieved through adaptive modulation, and fair rate allocation is based on the principle of generalized processor sharing to allocate the subcarriers adaptively among the users. The fair rate allocation problem is formulated as an optimization problem with the objective of maximizing system throughput while maintaining fairness (in terms of transmission rate) among the users. The “optimal” fair rate allocation is obtained by using the “Hungarian method.” A heuristic-based approach, namely the “iterative approach,” that is more implementation friendly is also presented. The throughput performance of the iterative fair rate allocation is observed to be as good as that of optimal fair rate allocation and is better than that of the static subcarrier allocation scheme. Also, the iterative fair allocation provides better fairness compared to that for each of the optimal and the static subcarrier allocation schemes. To this end, a queuing model is formulated to analyze radio link level performance measures such as packet dropping probability and packet transmission delay under the above rate allocation schemes. In this formulation, packet arrivals are modeled by the discrete Markov modulated Poisson process, which is flexible to model different types of traffic arrival patterns. The proposed framework for radio link level performance analysis of multirate OFDMA networks is validated by extensive simulations. Also, examples on the application of the proposed model for connection admission control and quality-of-service provisioning are illustrated

Adaptive Fair Rate Allocation

Instead of allocating a fixed set of subcarriers to each user when dynamic subcarrier allocation is used, multiuser diversity can be exploited to improve system throughput. In this case the channel information (i.e., SNR at the receiver) can be used to determine the optimal subcarrier allocation. Note that, with AM, for different users, each subcarrier can have different transmission rates depending on the modulation level. Under the given channel condition, the objective of the proposed fair rate allocation is to maximize system throughput while maintaining fairness of the transmission rates among all users according to their weights φ using a concept similar to GPS. However, note that the total transmission rate of the system is not constant and depends on the instantaneous SNR as well as the number of allocated subcarriers. Therefore, fairness among the users in terms of allocated transmission rate is maintained only over a period of time slots.

Formulation of the queuing model

In this section, we use a discrete-time Markov chain (DTMC) to model and analyze the radio link level queuing performance for a user in steady state. Although different users may have different arrival processes, and the pmf of the total transmission rate can be different, the queuing policy (i.e., service and dropping policy) is the same for all users. Therefore, given the pmf of transmission rate and the arrival process as the inputs, our general model can be applied to any radio link level queue.

1) Assumptions: With DTMC, we assume that the queue states are observed at the end of each time slot. The packets arriving in time slot t will be transmitted (i.e., serviced from the queue) in time slot $t + 1$ at the earliest. This is because the system state is observed at the end of a time slot. Note that in the proposed analytical framework for adaptive subcarrier allocation, the correlation in the channel error process (and hence the mobile speed) has not been taken into account. This can be considered using a finite-state Markov channel (FSMC) in a very general channel fading scenario (e.g., Nakagami fading) using the model in where the transition probability matrix for the channel states can be expressed as a function of channel correlation (and hence mobile speed). However, this would increase the dimensionality of the DTMC used here for queuing analysis

We have proposed adaptive optimal and iterative fair allocation schemes based on the implementation technique of GPS, which can exploit user diversity, channel state information, and multirate transmission at the radio link level. A queuing model for radio link level performance analysis has been developed considering a model for packet arrivals. Typical performance results from the radio link level queuing model have been presented for the proposed adaptive fair rate allocation schemes and have been compared with those for static allocation and TGPS schemes. The validity of the proposed queuing model has been assessed through simulations. To this end, we have shown two examples on the application of the proposed model for CAC and QoS provisioning. The proposed semi-analytical framework for radio link level performance evaluation would be useful for the design and engineering of multirate and multiuser OFDMA networks.

Rahman M, Yanikomeroglu H, Wong W (2009) [15] The investigation of co-channel interference mitigation techniques (such as, interference cancellation through receiver processing, interference randomization by frequency hopping, and interference avoidance through resource usage restrictions imposed by frequency and power planning) has become a key focus area in achieving dense spectrum reuse in next generation cellular systems such as 3GPP LTE, LTEadvanced, and WiMAX. In this paper, we propose an interference avoidance scheme for LTE downlink that uses dynamic inter-cell coordination facilitated through X2 interface among neighboring evolved UTRAN nodeBs (eNBs, i.e., LTE base stations). Proposed scheme is evaluated by extensive simulations and compared with a number of reference schemes available in the literature. It has been observed that the proposed scheme attains superior performance in terms of cell-edge and sector throughput compared to those in the reference schemes

Inter-cell interference can be reduced significantly with the traditional frequency reuse strategy as presented on cellular clustering static partition-based schemes. The higher the cluster size the greater the reduction in inter-cell interference. However, this improvement in interference can only be realized with the reduction in cell throughput. Although such a traditional reuse scheme might have been good enough to support traffic demands of the early networks, the rate requirements in the future systems warrant more aggressive reuse. In recent years, a large number of available studies in the literature consider reuse partitioning in which cell-edge UEs are assigned resources with higher reuse factors compared to the UEs at the cell-centre to obtain an effective reuse which is somewhat greater than 1 but not too high. In general these schemes are referred to as fractional. The restrictions on the usage of PRBs are determined from time-to-time at a time-interval within the channel coherence time, depending on the speed of the mobile. This interval is denoted as resource restriction refresh interval. Once the PRB restriction list is available at a sector, the scheduler can perform PRB scheduling based on its own criteria. We studied two variations of the proposed scheme; restricted PRBs are not used at all in one and these PRBs are used, however, only with reduced power (for example, with 10 dB lower) in another variation.

Jiaxin Zhang, Wenbo Wang, Xing Zhang, Yu Huang, Zhuowen Su and Zongchao Liu (2010) [8] To study the energy efficiency problem of heterogeneous cellular system, accurate and appropriate base station models for different scenarios are necessary, so it has been tried to find out the most appropriate models in different typical regions of the current mobile cellular network. In this paper, by dividing the research area into three typical regions (dense urban, urban and suburban) for detailed measurement of BS location, a set of approaches to test the spatial poisson point process and cluster process distribution is proposed based on the group users behaviour in real wireless networks. After numerous times of trials on different typical regions and various areas in the same type of region, a set of spatial models is proposed and analyzed.

It was concluded that spatial poisson point process is suitable only in urban and suburban regions but not for dense urban region. Key parameters of these models are provided as reference for the theoretical analysis and computer simulation to describe the complex spatial configuration more reasonably and reflect the real-world performance more precisely.

Neda Banivaheb, Keivan Navaie (2011) [1] This paper studies the impact of using multihop wireless adhoc network in conjunction with cellular networks under a probabilistic routing strategy. The objective is to obtain the outage probability of the two-dimensional hybrid CDMA network under path loss. In the proposed network the base stations are placed on a regular grid and users are distributed randomly according to a homogeneous Poisson point process. To obtain the outage probability of the proposed hybrid network, the outage probability of a cellular CDMA wireless network on both uplink and downlink as well as the outage probability of a multihop ad hoc CDMA network has been studied.

The results demonstrate that in order to improve the performance of a hybrid wireless network with a large density of users, it is beneficial to use multihop ad hoc communication. It has been studied, the outage probability of a hybrid cellular adhoc CDMA wireless network under a probabilistic routing strategy. It has been showed that considerable improvement in outage probability is not achieved by using ad hoc topology in low user density environment.

Jian Zhang, Lianhai Shan, Honglin Hu, and Yang Yang (2012) [7] This paper introduces the system architecture and application requirement for converged MCN and WSN, where mobile terminals in MCN are acting as both sensor nodes and gateways for WSN. And then, it discusses the joint optimization of converged networks for M2M communications. Finally, this work discusses the technical challenges in the converged process of MCN and WSN. This survey analyses the system applications requirements by using different WSN communication technologies. Further, it proposes the MCN-WSN joint optimization for QoS guarantee and many system technical challenges posed by the unique characteristics of converged MCN and WSN. The open issues in converged MCN and WSN are needed to be researched in order to promote more creative M2M applications.

The M2M networks applications are service-oriented. At this point, gateway is important equipment for realizing the interconnection between WSN and MCN. There are two types of gateway: fixed gateway and mobile UE gateway. In this scenario, the UE gateway is dual-mode and provides with both WSN and MCN interfaces. One of the major system requirements is how to select a proper wireless connection protocol that achieves at least the minimum requirements of the M2M sensing networks.

Jun Xia, Rui Yun, Kai Yu, Fei Yin, Haifeng Wang, Zhiyong Bu (2012) [10] This paper proposes an efficient accessing mechanism based on the assumption of integration of cellular and WSN via multimode UE. The instinct drawback of circumscribed sensing region of WSN restricts its application services. For that reason, cellular network, as widespread implemented, is regarded as potential partner for WSN since cell phone with much superiorities than sensor plays more and more important role in our daily life in terms of information collection and processing. Thus, the cellular user equipment (UE) which is flexible and promising multifunction device as the best candidate for enhancing WSN capability via mixing these two types of network.

UE equipped with WSN module can become multimode UE, which obtains the capability to access both mobile data network and wireless sensor network, and can act as a gateway for the WSN, combining mobility and large data transmission capability to distribute the measurement data from the sensor network. Multimode UE can access the wireless sensor cluster head, which as a part of wireless sensor network is considered.

Hoon Kim, Youngnam Han and Jayong Koo (2012) [5] The subcarrier allocation schemes for cellular orthogonal frequency division multiple access (OFDMA) systems with adaptive modulation and coding is considered. An LP formulation with the constraints of quality-of-service (QoS) and Limited bandwidth was made to achieve optimal system throughput. We propose an optimal subcarrier allocation scheme which allows cell coordination to assign subcarrier reuse factor and modulation scheme for each subcarrier. Also, to reduce computational complexity, a simplified cell coordination scheme is suggested. The capacity increase can he achieved by properly selecting modulation scheme and reuse factor of subcarrier, which is validated by simulation

Simplified sub channel allocation scheme: Sub channels are allocated optimally by OSAS with very high computational complexity. Therefore, a simpler algorithm, yet to achieve the objective, SSAS is proposed to reduce the system overhead and processing delay of the optimal solution by OSAS. For the purpose, a measure of spectral efficiency of a sub channel is addressed and a simpler cell coordination scheme

Optimal sub channel allocation scheme: In OSAS we assign sub channels by solving the LP problem subject to constraint the algorithm is represented by following steps.

1) MS report: Let I< SRFs and M modulation schemes are available. First, MS reports Rbi's to BS.

2) BS report: BS reports Ri3 to a radio network controller that communicates with BSs.

3) Cell coordination by LP problem: After RF's are received, the solution to the problem, NF, is provided with the known values such as RF, Tbi and G.

4) Subchannel allocation to BS and MS: A radio.network controller informs ATP's to cell b, which means CiNF subchannels of SRF k is allocated to cell 6. Then, N f subchannels are allocated to user i in cell b we have considered subchannel allocation schemes for cellular OFDMA systems where AMC are adopted and multiple subchannel reuse factors are available by a cell coordination. For the spectrally efficient utilization of sub channels, we proposed an optimal scheme where an constraints of QoS guarantees with limited bandwidth

Jian Feng, Lin Zheng, Jielin Fu, Zhenghong liu (2013) [6] In this paper, we present an optimal gateway selection mechanism to select the best gateway as the bridge of integrate WSN and MCN. To improve the overall network performance, we consider both WSN and MCN’s parameter to select the best gateway node as the bridge of integrating WSN and MCN, the number of hops between the gateway node and sensor node, the gateway load and the distance between the base station and gateway node, to achieve the best gateway selection. This scheme can enhance performance of packet delivery ratio (PDR), the average end-to-end packet delivery latency and throughput.

CHAPTER 3
SYSTEM ANALYSIS

3.1 EXISTING WSN AND MCN SYSTEMS

Wireless sensor communications are emerging as new communication types different from the conventional human-to-human communications. Sensor network communications are strongly application-oriented, and have been widely used in many areas, such as healthcare and environmental surveillance. As they are highly related to the particular market scenarios and have various optimization targets, different sensor networks may need different technologies. However, generally the terminals in WSN communications have less mobility. Moreover, in certain cases, some terminals can be more powerful by installing multiple Tx/Rx antennas when they are stationary or slowly moving within a fixed area and not limited to size.

In **Mobile Cellular Networks**, inter-cell interference is handled by the classical clustering technique for example, a reuse of 3. While this technique reduces interference for the cell-edge user terminals (UTs), it compromises system throughput due to resource partitioning. Such partitioning schemes may have been good enough for early networks focusing primarily voice service; however, they are inapplicable to future systems envisioned to support ranges of high data-rate applications, for example, video conference.

3.1.1 DRAWBACKS OF EXISTING MCN

- Frequency reuse problem in cell edge
- Flooding
- End to end delay
- Interference

3.1.2 DRAWBACKS OF EXISTING WSN

- Less mobility robustness,
- Small coverage, and
- Weak terminals.

3.2 PROPOSED SYSTEM

3.2.1 JOINT OPTIMIZATION OF CONVERGED MCN AND WSN

In the converged MCN and WSN, for MCN, WSN system performance can be improved with the help of MCN. The joint optimization is mainly focused on MCN-assisted WSN transmission. The proposed scheme mainly focusses the gateway selection/re-selection, load balance and emergency data adaptive transmission scheme to improve WSN system throughput, decrease transmission delay, reduce the data packet dropping rate and enhance the network lifetime.

The conventional network architecture of integrated MCN and WSN is hierarchical. All gateways are dual- mode and have both WSN and MCN interfaces. A group of wireless sensor nodes construct the data detecting plane, while the gateway and base station (BS) comprise the system control plane. WSN is controlled indirectly by the BS through the gateway. The gateway can just provide the access for WSN nodes, and forward the detected data to the backhaul network servers. Communications between WSN and MCN use a data channel at the gateway, which, however, decreases the system efficiency In the new network convergence approach, the converged MCN and WSN architecture is evolving from layered to flat to decrease the hierarchical signaling exchanging between the two networks. in the converged architecture the sensor nodes may have the ability to hear the downlink signal ing from the BS of MCN. The network architecture becomes flat. As a result, MCN can directly control and manage WSN, thus making WSN more efficient. For example, the BS can help the sensor nodes to choose the optimal transmission path to route the traffic. For the uplink, due to the limited transmission range of sensor nodes, the data is still routed by the gateway. Extra complexity is introduced to the sensor nodes to equip the downlink receiver, but the complexity will not be large since the device capabilities are much higher nowadays.

In the converged architecture, the impact to MCN and the complexity added to the sensor nodes should be evaluated to achieve an accept- able trade-off between the cost and performance gain. The authorization of the sensor nodes at the MCN needs to be studied. The information related to authorization can be relayed by the WSN gateway, which is already authorized in the MCN.

3.2.2 AIR-INTERFACE CONVERGENCE

Currently, narrowband technologies or spread spectrum transceivers are the main solutions for the air-interfaces of WSN (e.g. Bluetooth and ZigBee), while MCN uses different technologies (e.g. UMTS/LTE/Mobile WiMAX). To design a converged air-interface for MCN and WSN is a key challenge to gain the mutual benefit from the two types of networks.

The introduction of dual mode mobile terminals is a simple implementation, as shown in the left part of Fig. 2. The main limitation of this solution is that the terminal will frequently switch the mode in order to forward the data from WSN to BS. In MCN, orthogonal frequency-division multiplexing (OFDM) and orthogonal frequency- division multiple access (OFDMA) become the main solution for the air-interface. It has been shown that OFDM/OFDMA is an effective way to share the radio resources between systems with different bandwidth, e.g. the non-continuous OFDM (NC-OFDM) is an OFDM based spectrum pooling technique and has been gaining much attention recently.

As the higher data rate applications will be applied to WSN in the future, the OFDM based air-interface comes to an alternative for WSN, and thus, the full convergence of the air-interface becomes possible

3.2.3 NETWORK ARCHITECTURE CONVERGENCE

In the conventional WSN networks, there exists a group of wireless sensor nodes to detect data. The WSN gateway can provide the access for the WSN nodes, which WSN gateway just forward the detected data to the backhaul networks servers. And this is just individual integration of WSN and MCN, where the gateway is just located in the middle layer to manage the WSN nodes. The integrated network architecture is shown in the fig.3.1.

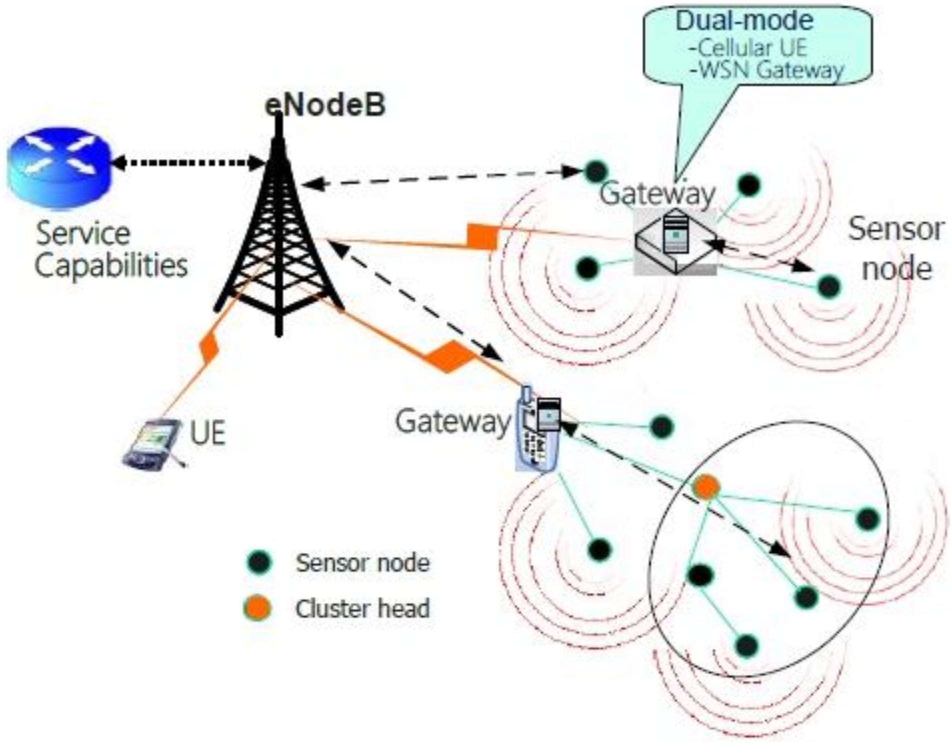

Fig.3.1 Integrated network architecture for MCN and WSN

In the converged networks, the data from WSN nodes can be forwarded to the eNodeB by the gateway directly. In this scenario, the eNodeB of cellular networks can control the WSN nodes, and can optimize the WSN to improve the WSN transmission efficiency. In converged MCN and WSN, the network architecture becomes flat while the conventional network is hierarchical. In the new network convergence approach, the control signaling can be exchanged directly between the MCN and WSN as shown in Fig.3.2, for instance, the nodes of WSN may have the ability of overhearing the downlink signaling from the eNodeB. As a result, MCN can directly control and manage WSN, which decreases the signaling exchange among sensor node, UE gateway and eNodeB.

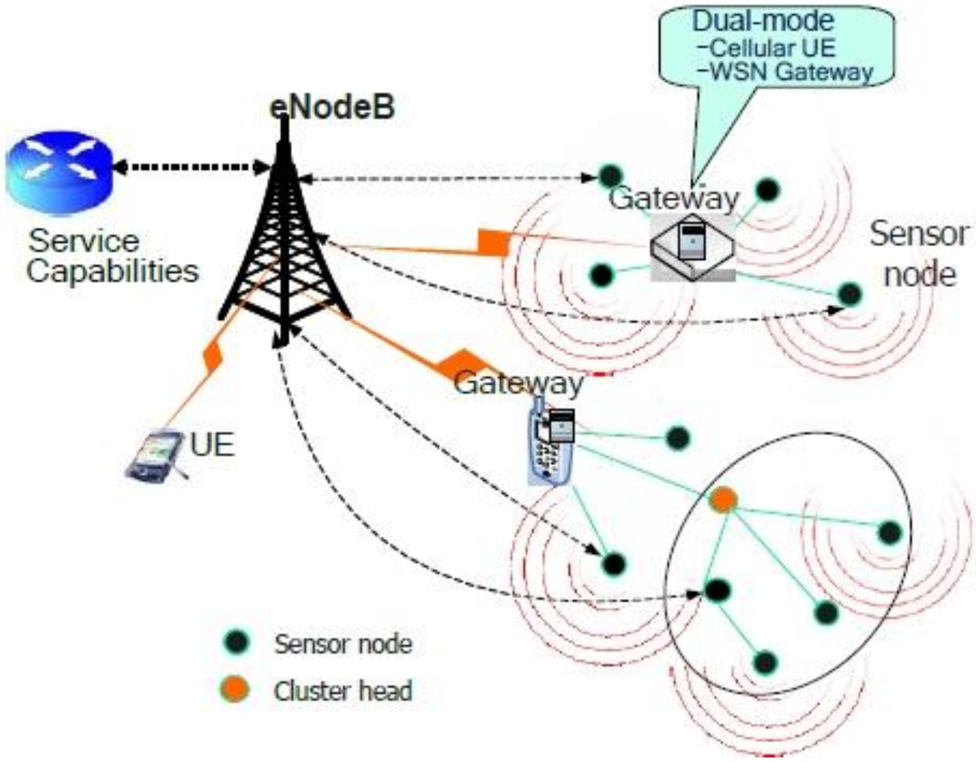

Fig.3.2 Converged network architecture for MCN and WSN

In the converged network architecture, the eNodeB can help sensor nodes to choose the optimal access gateway and transmission path. Besides this, more important information of WSNs can be stored in the cellular networks.

3.2.4 PROTOCOL CONVERGENCE

In the converged WSN and MCN scenario, the collected data from the sensor nodes can be routed to the BS by the gateway. Currently, the data channel between the two protocol stacks is usually implemented in the gateway,. In this case, data channels between the two independent stacks are implemented to exchange information. Since the network architecture and air-interface are highly converged for WSN and MCN, the protocol and control signaling should also be tightly converged for a real convergence of WSN and MCN. In such a converged network, MAC and network layer In the converged networks, the downlink and uplink control signaling should be designed, and some "cross-MAC" designs need to be implemented at the gateway. The new signaling may impact the current WSN and MCN standards. For thedownlink, entry/exit of WSN nodes and gateways may be managed by the BS, while for the uplink, the signaling from WSN nodes, e.g. requests for transmitting data, which can be triggered in periodic, on-demand, or event-driven ways, are also coordinated by the BS. Furthermore, in the PHY/MAC layer, the gateway needs to convey the sufficient/efficient control information to and from the BS for convergence optimization. The gateway needs to request the resources from the BS for uplink and downlink transmission, and forward some system information to sensor nodes.

In the MAC layer, a two-level resource allocation scheme should be considered for the con verged networks, especially for scenarios where there is large number of WSN nodes with heavy traffic. For example, the gateway can map the data and resource requests of sensor nodes to MCN, and reports to the BS; then the BS allocates a different WSN channel group to each gateway for intra-WSN communications according to the requested information from different gateways. In the network layer, when a mobile gateway enters the coverage area of WSN, it may cause gateway re-selection or even re-clustering of the wireless sensor nodes.

3.2.5 INTERFERENCE MANAGEMENT

Interference management has been a key concept for designing future high data-rate wireless systems that are required to employ dense reuse of spectrum. We present a novel dynamic interference avoidance scheme while converging with sensor networks that makes use of inter-cell coordination in order to prevent excessive inter-cell interference for bandwidth reservation to sector edge it comprised of a two-level algorithm - one at the base station level and the other at a central controller to which a group of neighbouring base stations are connected. This enhances the QoS parameters of both the networks.

Interference mitigation techniques are classified into three major categories such as interference cancellation through receiver processing, interference randomization by frequency hopping, and interference avoidance achieved by restrictions imposed in resource usage in terms of resource partitioning and power allocation. The benefits of these techniques are mutually exclusive, and hence, a combination of these approaches is likely to be employed in the system. Our focus on interference avoidance where a dynamic *inter-cell interference coordination* (ICIC) scheme that makes use of inter-cell coordination is investigate in a multi-cell environment with aggressive frequency reuse. The fractional frequency reuse (FFR) scheme has attracted the attention of the researchers in different standardization bodies and forums. The motivation behind FFR lies in the fact that UTs in the central area of a cell are more robust against interference due to low path-loss and hence they can tolerate higher reuse compared to those at the cell border suffering from high interference as well as high path-losses. Therefore, it makes sense to use different degrees of reuse factor for UTs in the cell-centre and cell-edge areas.

Partition-Based Static Co-ordination Schemes

If the available frequency spectrum is reused in each sector without imposing any restriction to frequency resource usage or power allocation, it achieves a reuse factor of 1, i.e., the worst inter-cell2 interference situation. On the other hand, if the available frequency spectrum is divided into three sub-bands and each sector is given a sub-band which is orthogonal to neighboring sectors sub-bands, then a reuse of 3 can be achieved. This clustering obviously gives improved inter-cell interference, however, with a significant resource restriction loss due to partitioning. Fig.s 1.a & 1.b show reuse 1 and 3 schemes respectively where total transmit power per sector transmitter remains constant in both cases. While reuse 1 does not employ any interference coordination, reuse 3 can be regarded as an extreme case of partition-based static interference coordination. The FFR schemes achieve an effective reuse factor between 1 and 3. Two variations of FFR schemes, namely SFR and PFR, are shown in Fig.s 1.c & 1.d and are elaborated below.

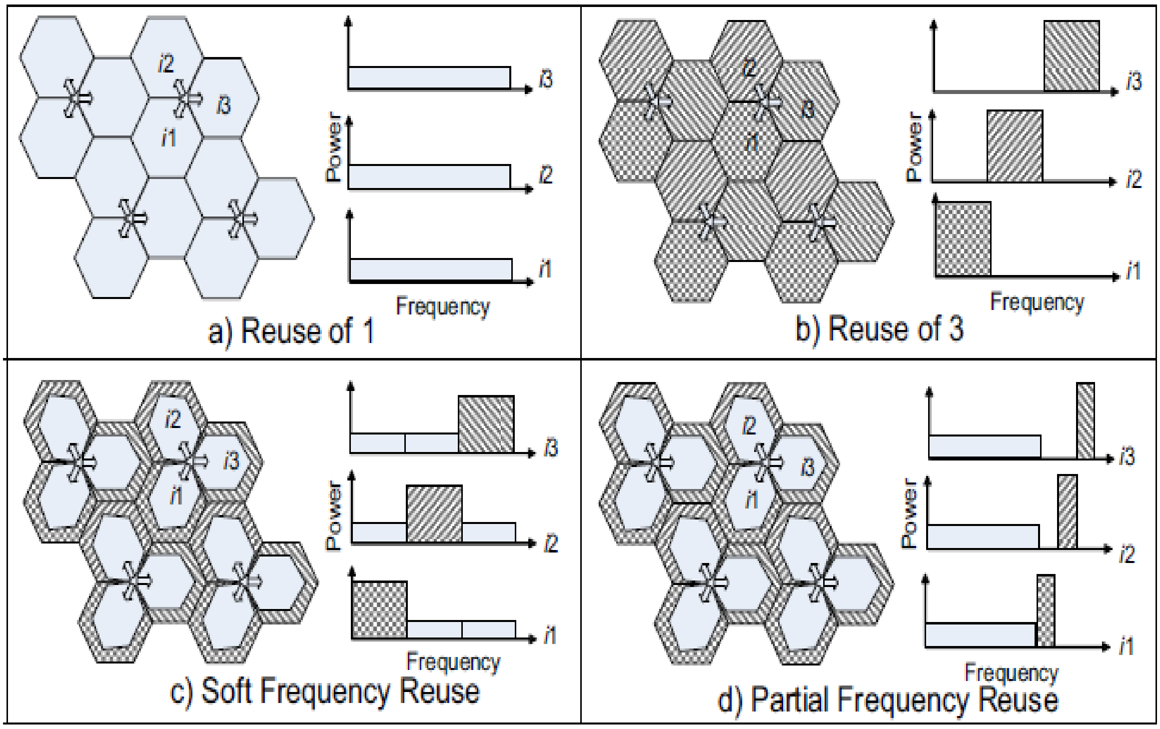

Fig.3.3 Frequency Reuse Techniques

Soft Frequency Reuse (SFR)

SFR, a variation of FFR, employs zone-based reuse factors in the cell-centre and the cell-edge areas. Restrictions are imposed in terms of allocation of frequency and power in the zones. The term *soft reuse* comes from the fact that effective reuse of the scheme can be adjusted by the division of powers between the frequencies used in the centre and edge bands.

In order to provide enhanced services to disadvantaged UTs near the cell boundary, SFR was proposed in within 3GPP LTE framework. For 3-sector cell sites, as shown in Fig. 1.c, the cell-edge band (also termed as major band) uses 1/3 of the available spectrum which is orthogonal to those in the neighboring cells and forms a structure of cluster size of 3. The cell-centre band (also called minor band) in any sector is composed of the frequencies used in the outer zone of neighboring sectors. Each group is assigned transmission power depending on the desired effective reuse factor while keeping the total transmission power fixed. Higher transmit power is used on the major band as shown in the right side of Fig.1.c Assume that the power per chunk is P_t/N in the case of reuse factor of 1 without coordination (as shown in Fig.1.a) and power per chunk used in the cell-edge (major) band is $\alpha_p P_t/N$ of the SFR scheme. Here, P_t is the total transmits power per sector, N is the number of chunks, and α_p is a power amplification factor whose value is greater than 1. As the total transmit power is constant, the power per chunk in the minor band of SFR would have to be $(3-\alpha_p)/2N$ giving a ratio of powers of minor to major bands as $(3-\alpha_p)/2\alpha_p$. The major band can be used in the cell-centre as well if it is not occupied by the cell-edge UTs, but the minor band is available to the centre area only. Due to this scheduling restriction, adjusting the power ratio from 0 to 1 effectively moves the reuse factor from 3 to 1. Therefore, SFR is seen as a compromise between reuse 1 and 3 in a network with trisector BSs. UTs are categorized into cell-edge and cell-centre based on user geometry determined by the received signal power (averaged over multipath fading) taking into account the large-scale path-loss, shadowing, and antenna gains.

Partial Frequency Reuse (PFR)

Contrary to SFR, the idea of the partial frequency reuse (PFR) is to restrict portion of the resources so that some frequencies are not used in some sectors at all. The effective reuse factor of this scheme depends on the fraction of unused frequency. The PFR and some of its variants are studied in the 3GPP and WINNER projects. An example of PFR for sites with 3 sectors is shown in Fig. 1.d. Let us assume that the available system bandwidth is β which is divided into inner and outer zones with β_i and β_o, respectively. Band β_i is used with a reuse factor of 1, and for the tri-sector BSs, the reuse factor for β_o is usually 3 in the outer zone. In this case, the effective frequency reuse factor is given by $\beta/(\beta_i+(\beta_o/3))$. Therefore, the effective reuse of PFR scheme is always greater than 1. Similar to SFR scheme, the power used on frequencies in the outer zone can be amplified.

Methodology

The proposed inter-cell interference coordination scheme is comprised of two separate algorithms;

- ✓ One is located at the BS level that prepares the chunk restriction requests
- ✓ The resides at the central controller that resolves restriction request conflicts

1. Based on the interference received by its UTs and their service status, each sector (via its BS) sends a request to the central controller
2. This request incorporates a tentative list of chunks to be restricted at the surrounding dominant interferer sectors.
3. This request also includes the utility measure of the chunks in the requesting sector. The central controller gathers all such requests and processes to prepare a refined list of chunk restrictions to be applied in all involved sectors in different cells.
4. The central controller sends the restriction decision to all involved sectors. This restriction process is refreshed from time-to-time within an interval which is shorter than the channel coherence time.
5. Scheduler takes the restriction decision into consideration. In order to achieve two-tier benefits, this approach of network layer resource coordination for interference avoidance can be complemented by physical layer processing defined as coordinated multi-point (COMP) transmission/reception in LTE-Advanced systems.
6. Using threshold function only rate deprived UTs are required To send information of two most dominant interference to the Serving BS causing additional signaling overhead

Interference avoidance algorithms

We describe the sector-level and the central algorithms as follows. Sector-level algorithm prepares utility matrix and prepares chunk restriction requests for each of its first-tier interferers. The central algorithm resolves any conflicting restriction requests and prepares final restriction list for each sector.

- ❖ Sector-level algorithm prepares utility matrix and prepares chunk restriction requests for each of its first-tier interferers.
    - Preparation of a utility matrix using the threshold-based restrictions derived from the channel conditions and UT demands.

- Preparation of restriction requests from the tentative chunk-to-UT allocation by using iterative Hungarian algorithm.

❖ The central algorithm resolves any conflicting restriction requests and prepares final restriction list for each sector.

  - The central controller receives requests from a cluster of BSs and resolves conflicting requests in an optimal manner for a particular chunk.

CHAPTER 4

SIMULATION SCENARIO AND RESULTS

4.1 SIMULATION SCENARIO

Simulation has been carried out using Network Simulator. For instance, a cell site containing 7 cells, and totally 103 nodes are deployed for simulation scenario. Some of the nodes are fixed and some are movable. The cellular nodes (UE) act as gateways for sensor network in every cell. Each cell is provided with a Base Station Controller to control and resolve dynamic routing strategies for the mobile gateways and sensor nodes. There is a network monitor deployed per every three cell to monitor the communication. The system resembles a real time scenario of combined cellular and sensor network as shown in fig.4.1.

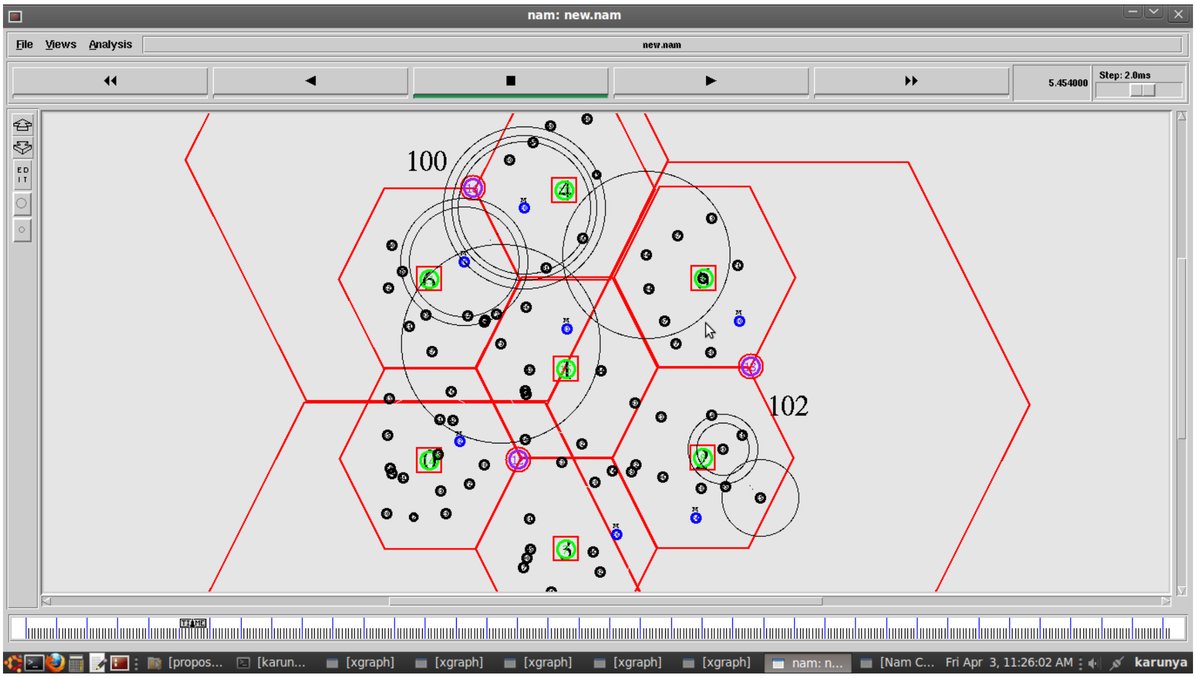

Fig.4.1. Simulation Setup

4.2 PARAMETER INITIALIZATION

The proposed method addresses the QoS parameters and interference considering mainly delay and packet loss. In order to evaluate the performance of communication, the below parameters are configured in the network simulator.

Channel Type : Wireless channel IEEE 802.11

Propagation model : Two Ray Ground

Network interface	:	Phy/WirelessPhy
Interface queue	:	Queue/DropTail/PriQueue
Antenna model	:	Omni-directional Antenna
max packet in ifq	:	1500
Packet Size	:	100-3000 bytes (variable)
Data Rate	:	Constant Bit Rate
No. of Nodes	:	103
Routing Protocol	:	AODV
Initial Energy	:	100 joules
Mobility	:	10 m/s
Transmission Range	:	150m

4.3 ENERGY CONSUMPTION

Energy consumption of a node is given by the formula,

$$\text{Energy Consumed} = \frac{\text{Average energy consumed in idle, sleep, txt and rxt mode}}{\text{Total energy consumed}}$$

The energy consumed per UE node for various network scenarios is plotted and shown in the fig.4.2. Obviously, for a normal cellular network, the energy consumed per user equipment is less as compared with the converged scenario. This is because the mobile UE acts as a gateway for its nearby sensor nodes and forwards the packets. Since it acts in dual mode, it requires to sacrifice more energy. But this is acceptable as the user equipment is battery operated and rechargeable. Hence additional energy consumption does not produce much impact while improving other Quality of Service parameters

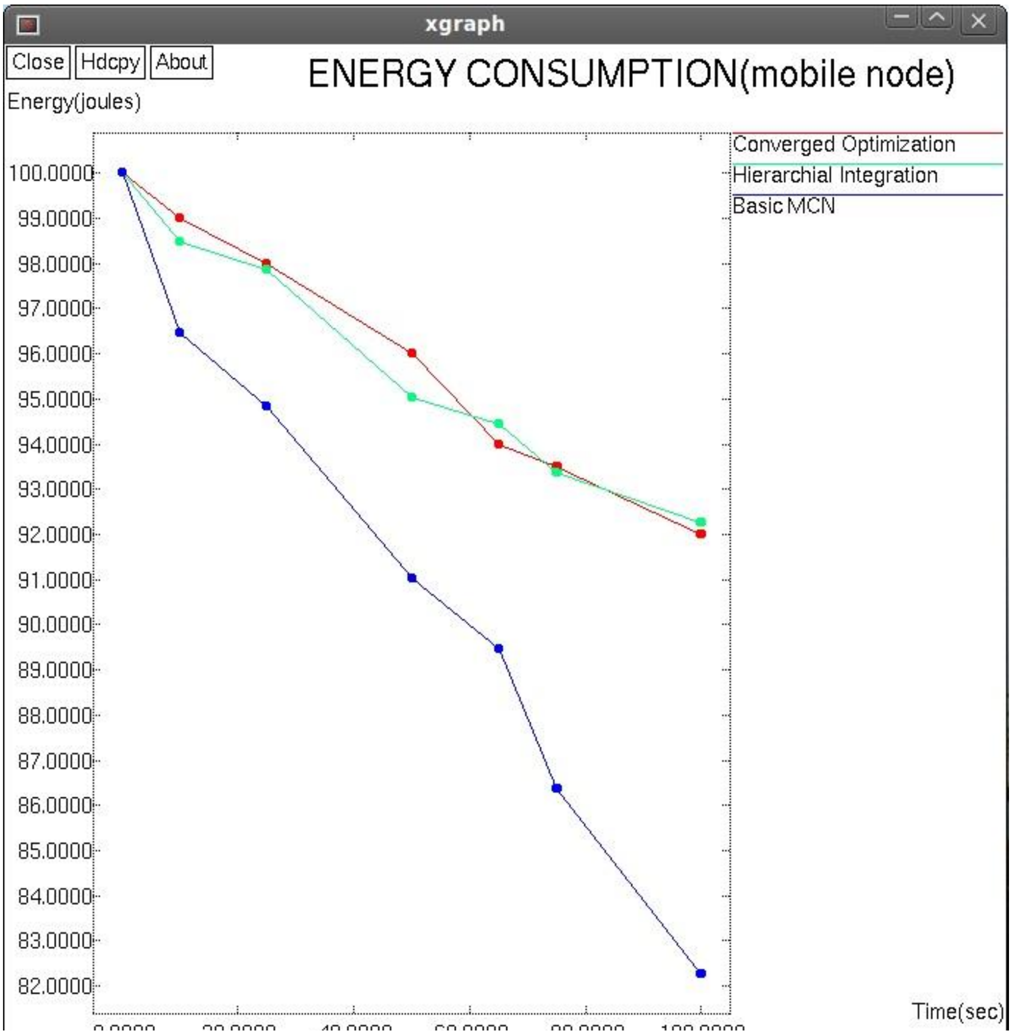

Fig.4.2. Energy Consumption

4.4 END TO END LATENCY

The average end to end latency of every node for various network scenarios is plotted and shown in the fig.4.3 It is defined as the inter arrival time between first packet time and second packet time divided over total packet delivery time.

The increased latency in existing hierarchical architecture is overcome in the proposed converged system and again the system is enhanced using interference avoidance algorithms as stated above. This provides additional reduction in latency and thereby improves the Qos.

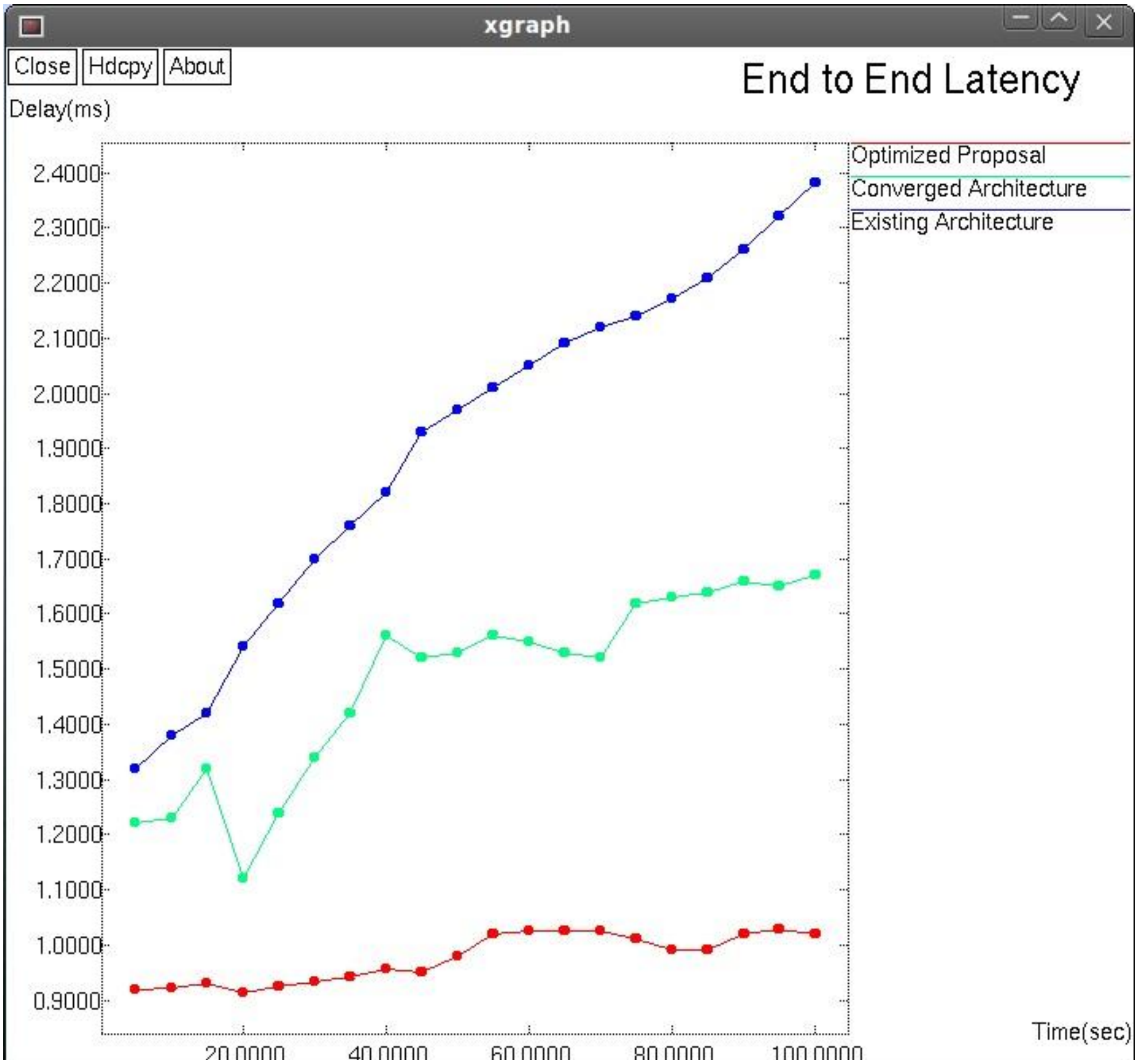

Fig4.3. End to End Latency

4.5 PACKET DELIVERY RATIO

Packet delivery ratio denotes the efficiency of a data transmission system. It is given by,

$$\text{PDR}(\%) = \frac{\text{Number of packets sent}}{\text{Number of packets received}} \times 100$$

The average packet delivery of every node for various network scenarios is plotted and shown in the fig.4.4 PDR is one of the QoS parameters and it is closely related to throughput. It is shown that in existing system, the average pachet delivery ratio is much less and it is enhanced by the implementation of flat converged proposal. Further in the enhanced proposal, the interference in the channel is avoided and this improves the delivery ratio to an optimized value.

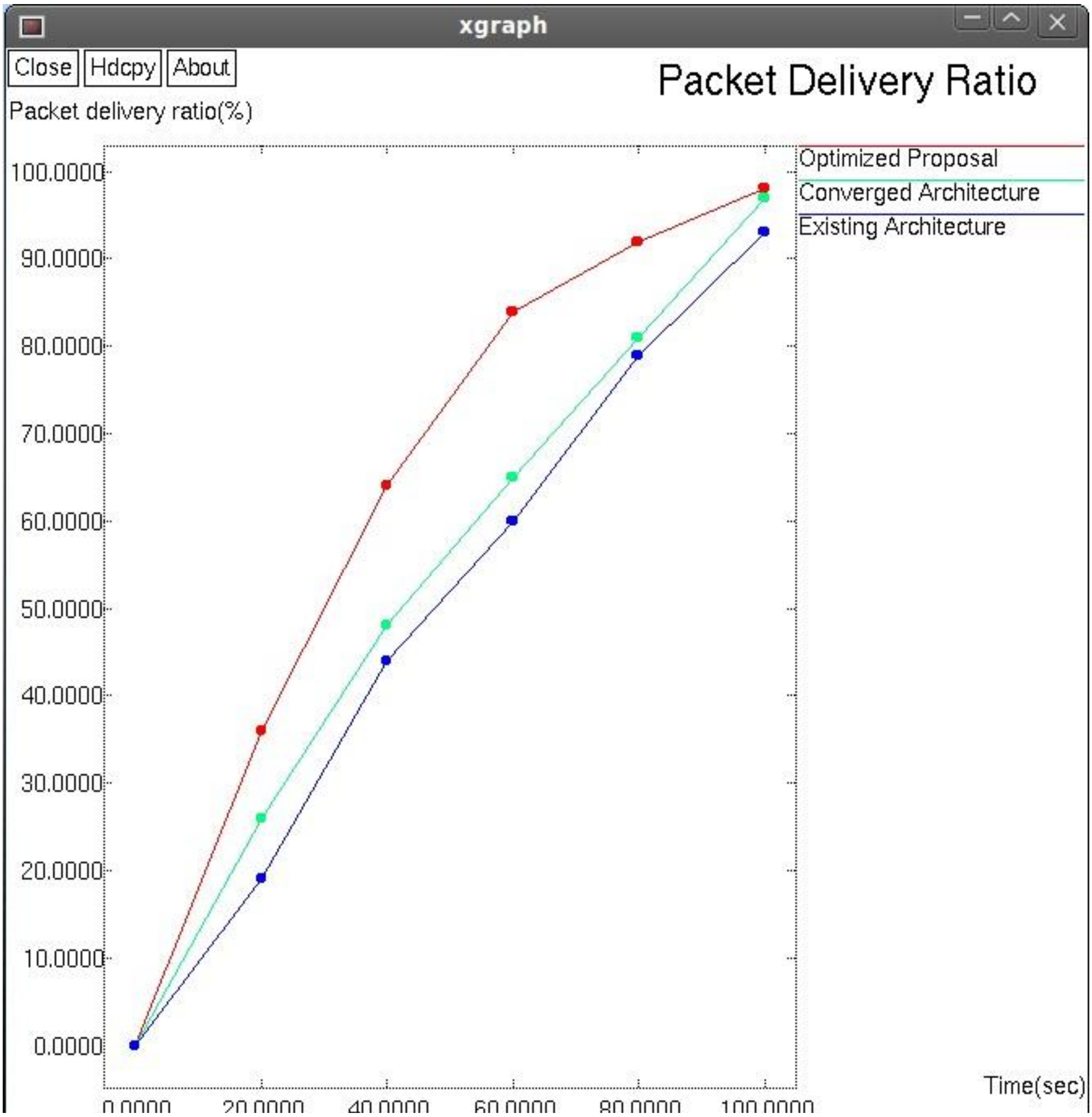

Fig.4.4. Packet Delivery Ratio

4.6 HAND-OFF DELAY

In a cellular system, as the distributed mobile transceivers move from cell to cell during an ongoing continuous communication, switching from one cell frequency to a different cell frequency is done electronically without interruption and without a base station operator or manual switching. This is called the handover or handoff. Typically, a new channel is automatically selected for the mobile unit on the new base station which will serve it.

Hand-off delay in a conventional MCN can be even reduced by implementing the proposed interference avoidance algorithm. This has been implemented and a graph is plotted and compared with existing MCN system. This is shown in fig.4.5

Fig.4.5. Hand-off Delay

4.7 THROUGHPUT

To attain both high spectral efficiency and good coverage within sectors/beams, a scheme based on coordinated scheduling between sectors of the same site, and the employment of frequency reuse factor above 1 only in outer parts of the sector, is proposed and evaluated. The resulting sector throughput increases with the number of active users. As shown in the fig.4.6, the enhanced proposal improves high yield in throughput as compared with the existing methods.

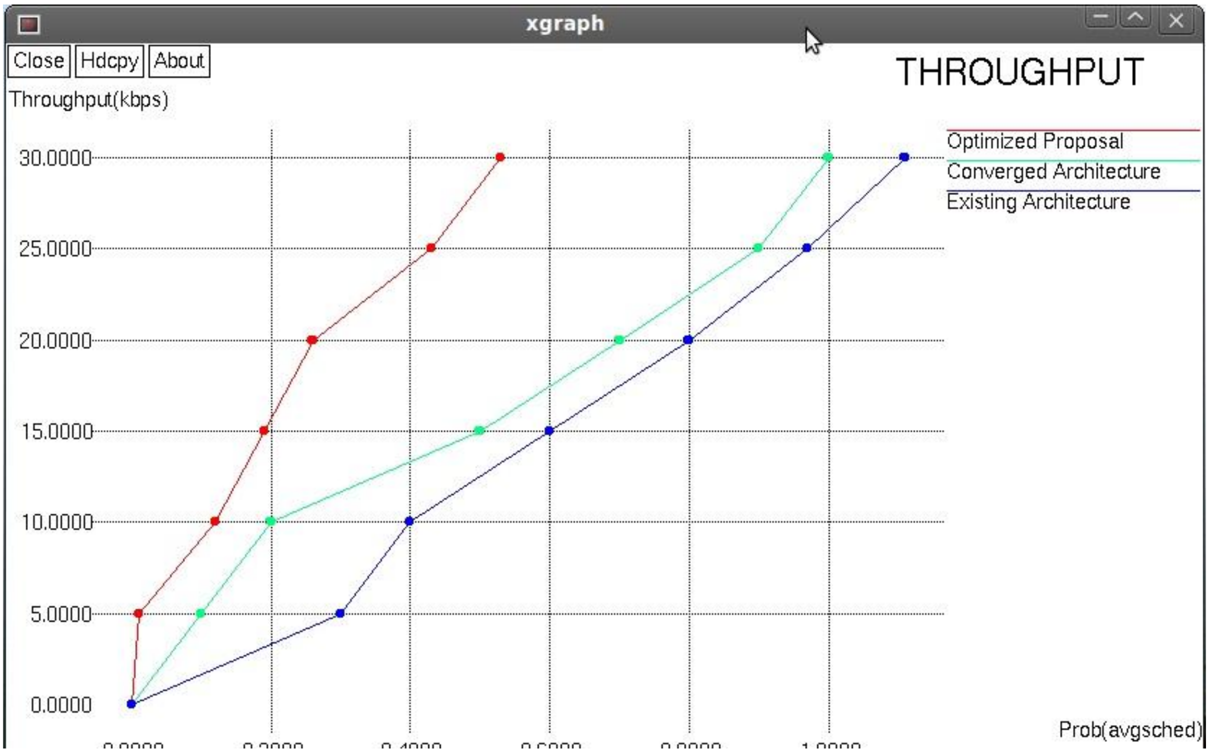

Fig.4.6 Throughput

A number of QoS parameters were improved by implementing the proposed scheme by a little sacrifice in energy of the gateway nodes (UEs). These parameters are averaged and tabulated to statistically show the improvement in network performance as given below.

PARAMETERS ON AVERAGE	EXISTING SYSTEM	CONVERGED SYSTEM	OPTIMIZED SYSTEM
LATENCY (ms)	1.9105	1.4765	0.9766
ENERGY (joules)	91.49	95.91	96.07
PDR (%)	49.16	52.83	62.33
HAND-OFF DELAY (ms)	0.5736	0.6372	0.4172
THROUGHPUT(Kbps)	5.5	9.25	17.27

Table.4.1 Comparison of Results

CHAPTER 5

SYSTEM SPECIFICATION

5.1 HARDWARE SPECIFICATION

To develop the simulation environment, IBM compatible personal computer with Pentium IV processor was used.

Main processor	:	Pentium IV processor 1.13 GHz
Hard disk capacity	:	40GB
Cache memory	:	512 MB
Monitor	:	SVGA Digital Colour Monitor
Keyboard	:	Standard
Mouse	:	Standard

5.2 SOFTWARE SPECIFICATION

Operating system	:	Ubuntu - Linux
Scripting language	:	Network Simulator 2.29
Protocol developed	:	C++

5.2.1 NETWORK SIMULATOR

Introduction

A network simulator is a software program that imitates the working of a computer network. In simulators, the computer network is typically modeled with devices, traffic etc and the performance is analyzed. Typically, users can then customize the simulator to fulfill their specific analysis needs. Simulators typically come with support for the most popular protocols in the use today, such as Wireless LAN, Wi-Max, UDP, and TCP. A network simulator is a piece of software or hardware that predicts the behavior of a network, without an actual network being present. NS is an object oriented simulator, written in C++, with an OTcl interpreter as a frontend.

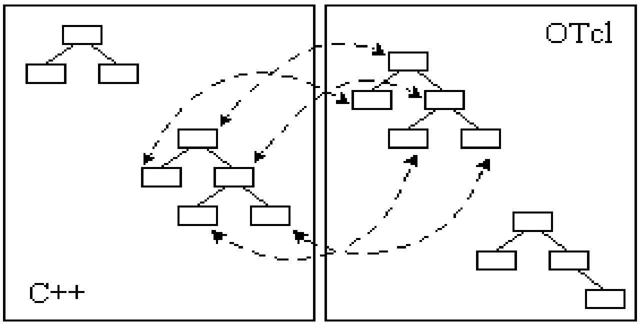

Fig.5.1 Network Simulator

The simulator supports a class hierarchy in C++ and a similar class hierarchy within the OTcl interpreter. The two hierarchies are closely related to each other; from the user's perspective, there is one-to-one correspondence between a class in the interpreted hierarchy and one in the compiled hierarchy. The root of this hierarchy is the class Tcl object. Users create a new simulator objects through the interpreter; these objects are instantiated within the hierarchy. The interpreted class hierarchy is automatically established through methods defined in the class Tcl object. There are other hierarchies in the C++ code and OTcl scripts; these other hierarchies are not mirrored in the manner of Tcl object.

Uses of Network simulators

Network simulators serve a variety of needs. Compared to the cost and time involved in setting up an entire test bed containing multiple networked computers, routers and data links, network simulators are relatively fast and inexpensive. They allow engineers to test scenarios that might be particularly difficult or expensive to emulate using real hardware- for instance, simulating the effects of sudden bursts in the traffic or a Dos attack on a network service. Networking simulators are particularly useful in allowing designers to test new networking protocols or changed to existing protocols in a controlled and reproducible environment. Network simulators simulate and then analyze the effect of various parameters on the network performance. Typical network simulators encompasses a wide range of networking technologies and help the users to build complex networks from basic building blocks like variety of nodes and links. With the help of simulators one can design hierarchical networks using various types of nodes like computers, hubs, bridges, routers, optical cross-connects, multicast routers, mobile units, etc. various types of Wide Area Network (WAN) technologies like TCP, ATM, IP etc and Local Area Network (LAN) technologies like Ethernet, token rings etc, can all be simulated with the typical simulator and the user can test, analyze various routing etc. There are a wide variety of network simulators, ranging from the very simple to very complex. Minimally a network simulator must a user to represent a network topology, specifying the nodes of the network, the links between the nodes and the traffic between the nodes. More complicated systems may allow the user to specify everything about the protocols used to handle network traffic. Graphical applications allow users to easily visualize the working of their simulated environment. Text based applications may provide a less intuitive interface, but may permit more advanced forms of customization. Others, such as GTNets, are programming- oriented, providing a programming framework that the user then customizes to create an application that simulates the networking environment to be tested.

Network Simulator 2 (NS2)

NS2 is an open- source simulation tool that runs on Linux. It is a discreet event simulator targeted at networking research and provides substantial support for simulation of routing, multicast protocols and IP protocols, such as UDP, TCP over wired and wireless (local and satellite) networks. It has many advantages that make it useful tool, such as support for multiple protocols and the capability of graphically detailing network traffic. Additionally, NS2 supports several algorithms in routing and queuing. Queuing algorithms include fair queuing, deficit round-robin and FIFO. REAL is a network simulator originally intended for studying the dynamic behavior of flow and congestion control schemes in packet switched data network. NS2 is available on several platforms such as FreeBSD, Linux, Sim OS and Solaris. NS2 also builds and runs under Windows

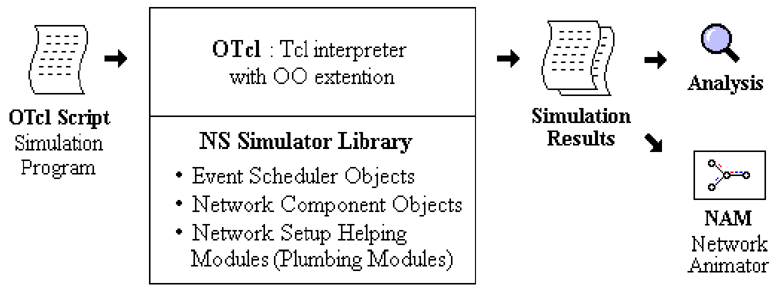

Fig.5.2. Simplified user's view of NS2

Installing NS

There are two ways to install NS: either independently by pieces or all at once (recommended one). Install all pieces at once using ns-allionexxx package. The following lines have to be changed in .bash _ profile file or in the corresponding file at our system:

export PATH=$PATH:..

export LD_ LIBRARY_ PATH=$LD_ LIBRARY_ PATH:…

export TCL_ LIBRARY=$TCL_ LIBRARY:…..

Node Basics

The basic primitive for creating a node is

set ns[new Simulator]

$ns node

The instance procedure node constructs a node out of simpler classifier objects. All nodes contain the following components:

1. An address or id_, monotonically increasing by 1 (from initial value o) across the simulation namespace as nodes are created
2. A list of neighbors (neighbor_)
3. A list of agents (agent_)
4. A node type identifier (node type_)
5. A routing module

Node Methods: Configuring the Node

Procedures to configure an individual node can be classified into:

1. Control functions
2. Address and Port number management, unicast routing functions
3. Agent management
4. Adding neighbors

Control functions

1. $node entry returns the entry point for a node. This is the first element which will handle packets arriving at that node. The Node instance variable, entry_, stores the reference this element. For multicast nodes, the entry point is the switch_ which looks at the first bit to decide whether it should forward the packet to the unicast classifier, or the multicast classifier as appropriate.

2. $node reset will reset all agents at the node.

Address and port number management

1. The procedure **$node id** returns the node number of the node. This number is automatically incremented and assigned to each node at creation by class Simulator method, $ns node.
2. The procedure **$node agent <port>**returns the handle of the agent at the specified port. If no agent at the specified port number is available, the procedure returns the null string.
3. The procedure **alloc_ port** returns the next available port number. Is uses an instance variable, np_, to track the next unallocated port number.
4. The procedures, **add_ route** and add-routes, are used by unicast routing to add routes to populate the classifier.

Agent management

Given an <agent>, the procedure attach{} will add the agent to its list of agents_, assign a port number the agent and set its source address, set the target of the agent to be its (i.e., the node's) entry{}, and add a pointer to the port demultiplexer at the node (dmux_) to the agent at the corresponding slot in the dmux_ classifier. Conversely, detach{} will remove the agent from agents_, and points the agent's target, and the entry in the node dmux_ to mullagent.

Tracking Neighbors

Each node keeps a list of its adjacent neighbors in its instance variable, neighbor_. The procedure add neighbor {} adds a neighbor to the list. The procedure neighbors {} returns this list.

Creating a Tcl scenario

To define trace files with the data that needs to be collected from the simulation, we have to create these files using the command open:

#open the trace file

set traceFile [open out.tr w]

$ns trace-all $traceFile

#open the Nam trace file

set namFile [openout.nam w]

$ns namtrace-all $namFile

#define the TCP agent

Set tcp [new Agent/TCP]

$ns attach-agent $n(0) $tcp

Set sink [new Agent/TCPSink]

$ns attach-agent $n(1) $sink

$ns connect $tcp $sink

Node Configuration

Node configuration essentially consists of defining the different node characteristics before creating them. They may consists of the type of addressing structure used in the simulation, defining the network components for mobile nodes, turning on or off the trace options at Agent/Router/MAC levels, selecting the type of adhoc routing protocol for wireless nodes or defining their energy model. The node- configure command would look like the following:

```
$ns_ node-configure –addressType hierarchical\
-adhocRouting AODV\
-11TypeLL\
-macTypeMac/802_11\
-ifqType Queue/DropTail/PriQueue\
-ifqLen50\
-antType Antenna/OmniAntenna\
-propType propagation/TwoRayGround\
-phyType Phy/WirelessPhy\
-topologyInstance $topo\
-channel Channel/wirelessChannel\
-agentTrace ON\
```

-routerTrace ON\

-macTrace OFF\

-movement Trace OFF

Simulation Procedure

Run the script by typing at the Console as

ns filename.tcl

On completion of the run, Trace output file “filename-out.tr” and nam output file “filename-out.nam” are created. Running filename-out.nam, the mobile nodes moving in the nam window can be seen. The active senders start informing the network about its presence and begin sending data according to the random progress method.

The finish procedure is given as

```
proc finish{} {
$ns flush-trace
close $r
close $nf
exec nam –r filename. nam &
exit 0
}
```

In the finish procedure, the trace file buffer is cleared and the graphs are generated in the terminal in a pipelined manner. $ns is used to close the trace field. Now the animator field is generated using command

exec nam filename.nam

To run the file **$ns run** command is used and the tcl script is executed.

To execute the graph **exec ns graph.tcl command is used.**

CHAPTER 5

CONCLUSION AND FUTURE WORK

MCN and WSN are evolving from heterogeneous to converged architecture in order to satisfy the increasing requirements of M2M communications, where many joint optimized methods and technical challenges still exist. This survey analyzed the system application requirements and a number of factors for optimization of Quality of Service parameters. Further, for the MCN-WSN joint optimization, gateway selection/re-selection, load balancing scheme, enhanced data handling schemes will be analysed in the future work. Many system technical enhancements especially by interference avoidance techniques, posed by the unique characteristics of converged MCN and WSN has been proposed here. The open issues in converged MCN and WSN will be researched in the future work in order to promote more creative applications.

CHAPTER 6

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