Design and Simulation of Wireless Sensor Network scenario for underground coal mines

Thesis submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology

In

Electronics and Instrumentation Engineering

By

Debasish Brahma

(Roll number: 107EI026)

Department of Electronics and Communication Engineering

National Institute of Technology Rourkela

May 2011

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Under the guidance of

Prof. S. K. Patra

Department of Electronics and Communication Engineering

National Institute of Technology Rourkela

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Certificate:

This is to certify that the work in this thesis report titled **"Design and Simulation of Wireless Sensor Network scenario for underground coal mines"** by **Debasish Brahma** has been carried out under my supervision in partial fulfillment of the requirements for the degree of **Bachelor in Technology** in Electronics and Instrumentation Engineering during the session 2010-2011 in the department of Electronics and Communication Engineering, National Institute of Technology Rourkela and his work has not been submitted elsewhere for a degree.

Place: Rourkela **(Prof. Sarat Kumar Patra)**

Date: May 16, 2010 **Department of ECE**

Acknowledgement:

Many people have been involved, directly or indirectly, in the completion of this thesis and I would like to take this opportunity to express my gratitude to them. I would firstly like to sincerely thank my project guide, Prof S.K.Patra, for being a constant source of inspiration throughout the course of this project work and this work would not have been possible without his valuable guidance. I would like to express my gratitude to all the research scholars whose works were referred to by me during the completion of this project work. I would also like to thank Mr. Sanatan Mohanty for his invaluable contribution. A special mention about *Qulanet (a* WSN simulation software*)* and its developers; which has been used in the simulation of the scenarios.

Debasish Brahma

107EI026

Abstract:

This thesis is a summary of all the work that has been done by me during my B-Tech final year project work. The main purpose was to provide an implementable design scenario for underground coal mines using wireless sensor networks (WSNs). The main reason being that given the intricacies in the physical structure of a coal mine, only low power WSN nodes can produce accurate surveillance and accident detection data. The work mainly concentrated on designing and simulating various alternate scenarios for a typical mine and comparing them based on the obtained results to arrive at a final design. The simulations were done in Qulanet-4.5 simulator. The bytes send, received, throughput, MAC layer and physical layers were analyzed in the process for all the scenarios. The final results show a complicated arrangement of Personal Area Networks and a multiple hopping based PAN coordinator communication to ensure optimum utilization of the power scarce nodes.

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1. INTRODUCTION:

1.1 Motivation:

Surveillance in underground coal mines is of utmost importance in the modern era owing to the large scale industrial expansion and alongside the rising human right violations. The number of accidents occurring inside these underground coal mines is myriad both in number and the type. Such is the case that most of the accidents often go unreported and hence unchecked. The mines mainly consist of random passages and branch tunnels. This disorganized structure of a coal mines makes it difficult for the deployment of any networking skeleton. The non-communicability with the ground RF ambience inside an underground mine further complicates the matter. The network infrastructure in an underground environment is completely isolated from the ground electromagnetic signals and thus has to generate its own environment of connectivity. This Power scarcity is another major area of concern. Due to the complicated physical topology of a mine deployment of wired power becomes clumsy which calls for a minimum sized network infrastructure.

WSN (Wireless Sensor Networks) owing to their huge applicative potential offer a practical solution to the problem mentioned above. A typical WSN mainly consists of spatially distributed random sensor nodes which independently work and collect some data which is then sent the some central analyzing centre where the data is collated and analyzed for further action. The topology and the network structure of WSN is not a strict standard and can be varied and designed as per the requirements. The WSNs have been lately successfully employed in various applications ranging from area monitoring, landslide detection to health monitoring and other bio-medical applications. This success can be attributed to the recent emergence of the simulation tools which can offer a real time simulation of the entire sensor network. The simulation software used in this context is Qualnet-4.5. A product of Qualcom.inc, it is highly relevant and offers a wide range of parameters for very accurate simulation. This main aim of the project is to successfully design and simulate the WSNs to be employed in the mines scenario. Various topologies have been tried out by variation of certain parameters to achieve an optimum value of the required output. The project works on a novel idea of simultaneous and integrated deployment of both the wired and wireless sensor networks inside the underground mine to achieve an optimum condition. The present work mainly deals with the wireless network employed.

1.2 Outline of the Work:

This main aim of the project is to successfully design and simulate the WSNs to be employed in the mines scenario. Various topologies have been tried out by variation of certain parameters to achieve an optimum value of the required output. The project works on a novel idea of simultaneous and integrated deployment of both the wired and wireless sensor networks inside the underground mine to achieve an optimum condition. The present work mainly deals with the wireless network employed**.**

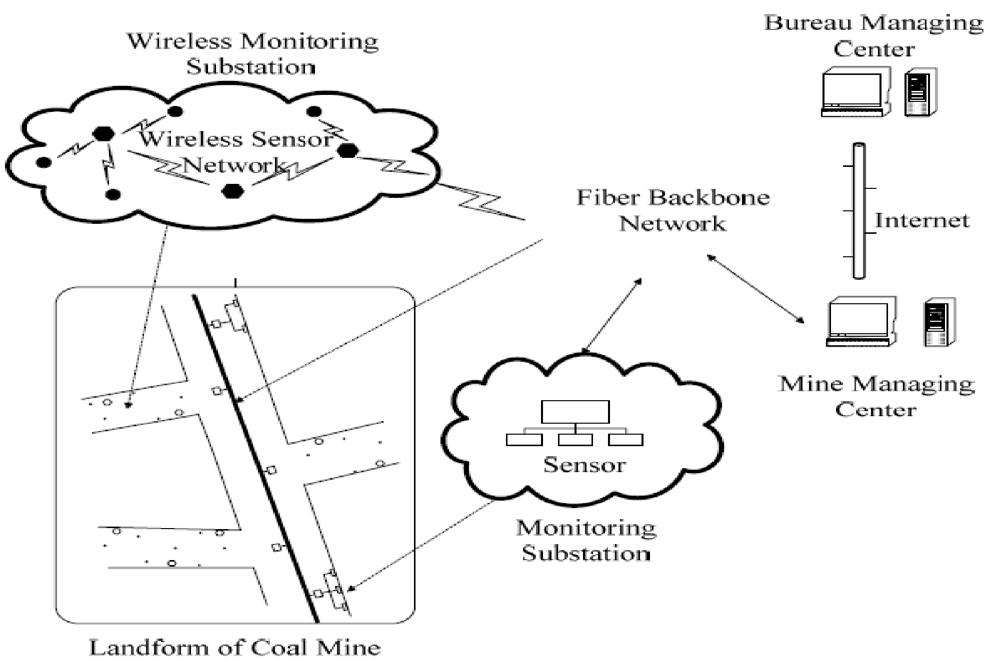

Figure1: Figure of a mine safety system using wired and wireless links

2. Wireless Sensor Networks:

Wireless Sensor Networks (WSN*)* have become very popular due to the progress made in wireless communication, IT and electronics field. WSN consists of tiny, autonomous and compact devices called sensor nodes deployed in a remote area to detect phenomena, collect, process data and transmit sensed information to users. A multifunctional sensor with low-cost of development and low power consumption has received increasing attention from various industries. Sensor nodes in WSNs are small sized and are capable of sensing, gathering and processing data while communicating with other connected nodes in the network, via radio frequency (RF) channel **[4].**

WSN term can be broadly sensed as devices range from laptops, PDAs or mobile phones to very tiny and simple sensing devices. At present, most available wireless sensor devices are considerably constrained in terms of computational power, memory, efficiency and communication capabilities due to economic and technology reasons. That's why most of the research on WSNs has concentrated on the design of energy and computationally efficient algorithms and protocols, and the application domain has been confined to simple data-oriented monitoring and reporting applications **[2].** WSNs nodes are battery powered which are deployed to perform a specific task for a long period of time, even years. If WSNs nodes are more powerful or mains-powered devices in the vicinity, it is beneficial to utilize their computation and communication resources for complex algorithms and as gateways to other networks. New network architectures with heterogeneous devices and expected advances in technology are eliminating current limitations and expanding the spectrum of possible applications for WSNs considerably**[4]**.

2.1 Wireless sensor node architecture:

The basic block diagram of a wireless sensor node is presented in Figure 1.1. It is made up four basic components: a sensing unit, a processing unit, a transceiver unit and a power unit. There can be application dependent additional components such as a location finding system, a Power-generator and a Mobilizer**[4]**.

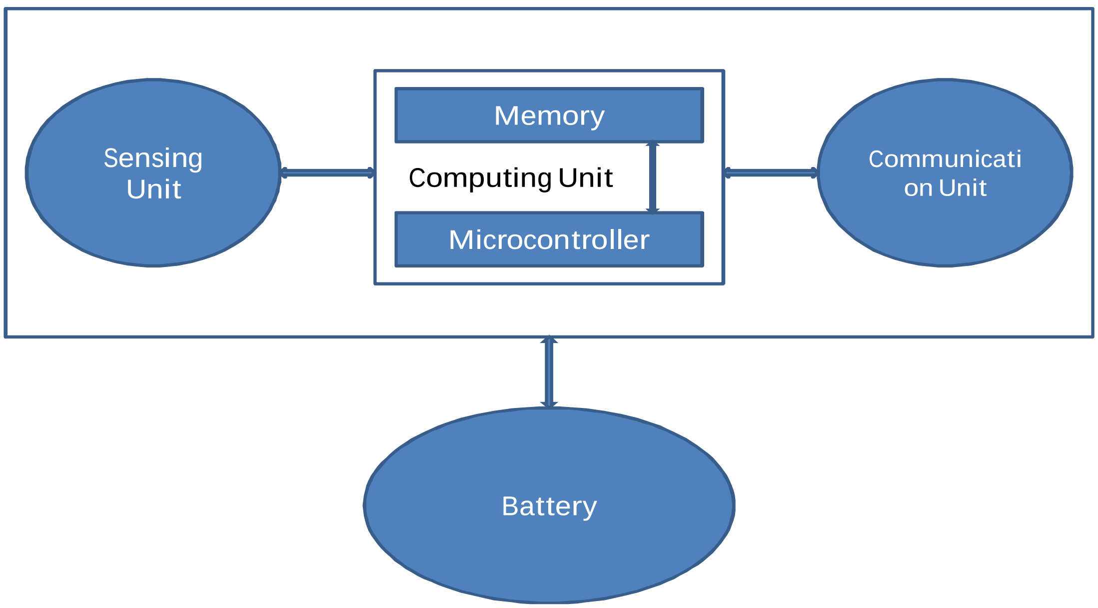

Figure 2: Architecture of a Wireless Sensor Node

- **The Sensing Unit**: It consists of the sensor deployed at the node which collects data at the ground level. This data is the physical or the raw data which is sampled and converted to the analog domains and then into the digital form which is then converted into digital forms which is then sent to the processing unit. Sensing units are usually composed of two subunits: sensors and analog to digital converters. Sensor is a device which is used to translate physical phenomena to electrical signals. Sensors can be classified as either analog or digital devices. There exists a variety of sensors that measure environmental parameters such as temperature, light intensity, sound, magnetic fields, image, etc.

- **The Processing Unit:** The processing unit mainly provides intelligence to the sensor node. The processing unit consists of a microprocessor, which is responsible for control of the sensors, execution of communication protocols and signal processing algorithms on the gathered sensor data. Commonly used microprocessors are Intel's Strong ARM microprocessor, Atmel’s AVR microcontroller and Texas Instruments' MP430 microprocessor. In general, four main processor states can be identified in a microprocessor*: off, sleep, idle and active*. In sleep mode, the CPU and most internal peripherals are turned on, and can only be activated by an external event (interrupt). In idle mode, the CPU is still inactive, but other peripherals are active.

- **Transmission Unit:** Similar to microcontrollers, transceivers can operate in *Transmit, Receive, Idle and Sleep* modes. An important observation in the case of most radios is that, operating in *Idle* mode results in significantly high power consumption, almost equal to the power consumed in the *Receive* mode. Thus, it is important to completely shut down the radio rather than set it in the *idle* mode when it is not transmitting or receiving due to the high power consumed. Another influencing factor is that, as the radio's operating mode changes, the transient activity in the radio electronics causes a significant amount of power dissipation. The sleep mode is a very important energy saving feature in WSNs.

- **Battery -** The battery supplies power to the complete sensor node. It plays a vital role in determining sensor node lifetime. The amount of power drawn from a battery should be carefully monitored. Sensor nodes are generally small, light and cheap, the size of the battery is limited. Furthermore, sensors must have a lifetime of months to years, since battery replacement is not an option for networks with thousands of physically embedded nodes. This causes energy consumption to be the most important factor in determining sensor node lifetime.

3. *Qualnet-4.5*:

QualNet is a fast, scalable and hi-fidelity network modeling software. It enables very efficient and cost-effective development of new network technologies. By building virtual networks in a lab environment, you can test, optimize, and integrate next generation network technologies at a fraction of the cost of deploying physical *testbeds*. It uses the *QualNet Graphical User Interface (GUI)* for an integrated network simulation experience for network design, execution and animation, and analysis. QualNet is network modeling software that predicts performance of networking protocols and networks through simulation and emulation **[3].** Using emulation and simulation allows you to reproduce the unfavorable conditions of networks in a controllable and repeatable lab setting.

QualNet provides the following key benefits:

• **Speed.** QualNet can support real-time and faster than real-time simulation speed, which enables software-in-the-loop, network emulation, hardware-in-the-loop, and human-in-the-loop exercises.

• **Scalability.** QualNet supports thousands of nodes. It can also take advantage of parallel computing architectures to support more network nodes and faster modeling. Speed and scalability are not mutually exclusive with QualNet.

• **Model Fidelity**. QualNet offers highly detailed models for all aspects of networking. This ensures accurate modeling results and enables detailed analysis of protocol and network performance.

• **Portability.** QualNet runs on a vast array of platforms, including Linux, Solaris, Windows XP, and Mac OS X operating systems, distributed and cluster parallel architectures, and both 32- and 64-bit computing.

• **Extensibility**. QualNet connects to other hardware & software applications, such as OTB, real networks, and STK, greatly enhancing the value of the network model.

4. ZIGBEE and supported wireless network topologies:

ZigBee is an emerging worldwide standard for wireless personal area network based on the IEEE 802.15.4-2003 standard for Low-Rate Wireless Personal Area Networks (LR-WPANs). Since ZigBee devices are designed for low cost and low data rates, it is used in many sensor network applications such as smart homes, building automation, and industrial automation. As well as these initial market application and products, ZigBee mobile phone systems are emerging as a new market. ZigBee provides self-organized, multi-hop, and reliable mesh networking with long battery lifetime. Two different device types can participate in an LR-WPAN network: a full-function device (FFD) and a reduced-function device (RFD). The FFD can operate in three modes serving as a PAN coordinator, a coordinator, or a device. An FFD can talk to RFDs or other FFDs, while an RFD can talk only to an FFD. An RFD is intended for applications that are extremely simple, such as a light switch or a passive infrared sensor. They do not have the need to send large amounts of data and may only associate with a single FFD at a time. Consequently, the RFD can be implemented using minimal resources and memory capacity **[5]**. After an FFD is activated for the first time, it may establish its own network and become the PAN coordinator. All star networks operate independently from all other star networks currently in operation. This is achieved by choosing a PAN identifier, which is not currently used by any other network within the radio sphere of influence. Once the PAN identifier is chosen, the PAN coordinator can allow other devices to join its network. An RFD may connect to a cluster tree network as a leave node at the end of a branch, because it may only associate with one FFD at a time. Any of the FFDs may act as a coordinator and provide synchronization services to other devices or other coordinators. Only one of these coordinators can be the overall PAN coordinator, which may have greater computational resources than any other device in the PAN**[4]**.

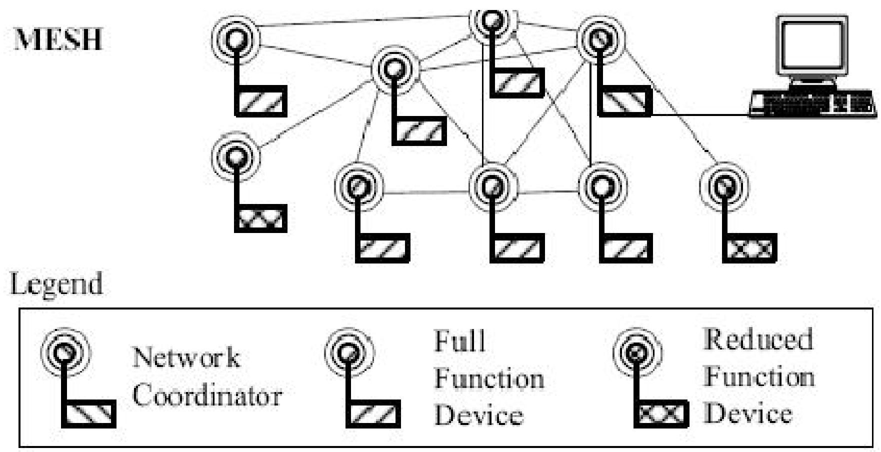

Figure 3: A MESH Network Topology

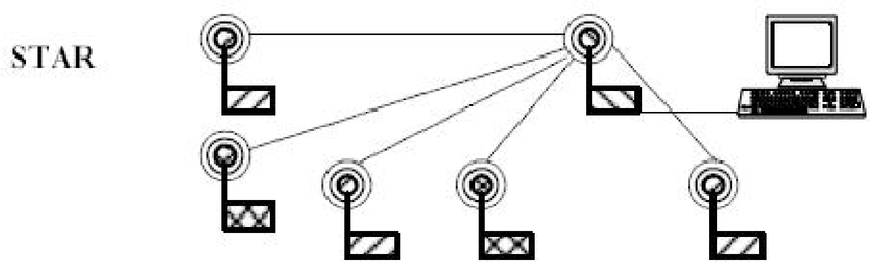

Fig. 4: A STAR Network Topology

5. DESIGN:

Figure (x) shows a simplified section of a coal mine. Coals mines are underground places where there are tunnels dug at convenient places to dig the coal out of it. The tunnels are highly branched and have intermediary coal blocks which serve as a perfect RF blockage system. As seen from the figure the nodes marked by numbers on them have to come up with some intermediary steps and multi-hopping techniques to avoid any sort of data losses and RF blockages. The design scenario is a 1500m cross 1500m patch with two parallel tunnel lines with a tunnel below. The coal block at the centre is assumed to be rectangular for simplicity purposes. The side tunnels have sensor nodes placed randomly along the walls and all these sensor nodes have a PAN coordinator to send all the collected data. This data is them passed on through a chain of PAN coordinators to finally reach the base station 17. In an actual implementation, all these base stations would be inter-connected and finally sending the data to the server on the ground surface.

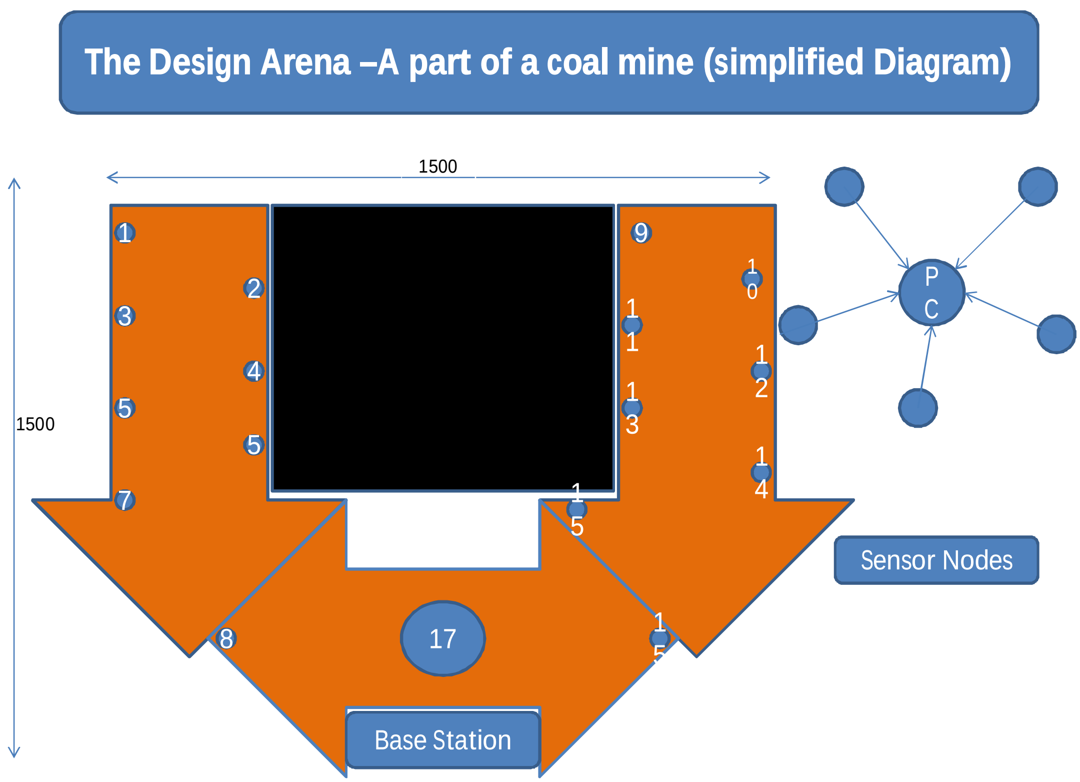

Figure 5: Layout of the Coal mine design Scenario

QualNet Configuration File:

This is a system generated configuration file produced for the desined scenario. It contain the details of all the parameters used in the desining of the scenario.

(These set of configurations have been used for all further simulations.)

VERSION 4.5
EXPERIMENT-NAME Qualnet
EXPERIMENT-COMMENT none
SIMULATION-TIME 30S

SEED 1

Parallel Settings

Terrain:

COORDINATE-SYSTEM CARTESIAN
TERRAIN-DIMENSIONS (1500, 1500)
DUMMY-ALTITUDES (1500, 1500)
TERRAIN-DATA-BOUNDARY-CHECK YES

Node Positioning

The number of nodes being simulated.
DUMMY-NUMBER-OF-NODES 11
The node placement strategy.
NODE-PLACEMENT FILE
NODE-POSITION-FILE Part1.nodes

Mobility:

MOBILITY NONE
MOBILITY-POSITION-GRANULARITY 1.0
If yes, nodes get their altitude coordinate from the terrain file, if one is specified.
MOBILITY-GROUND-NODE NO

Wireless Settings:

Channel:

PROPAGATION-CHANNEL-FREQUENCY 2400000000
PROPAGATION-MODEL STATISTICAL

Signals with powers below PROPAGATION-LIMIT (in dBm) (before the antenna gain at the receiver) are not delivered.
PROPAGATION-LIMIT -111.0
2-Ray Pathloss Propagation Model
PROPAGATION-PATHLOSS-MODEL TWO-RAY
PROPAGATION-SHADOWING-MODEL CONSTANT
PROPAGATION-SHADOWING-MEAN 4.0
PROPAGATION-FADING-MODEL NONE

Radio/Physical Layer

ENERGY-MODEL-SPECIFICATION NONE
BATTERY-MODEL NONE
PHY-MODEL PHY802.11b
PHY802.11-AUTO-RATE-FALLBACK NO
bandwidth in bps. supported data rates: 1Mbps, 2Mbps, 5.5Mbps, 11Mbps
PHY802.11-DATA-RATE 2000000
PHY802.11b-TX-POWER--1MBPS 15.0
PHY802.11b-TX-POWER--2MBPS 15.0
PHY802.11b-TX-POWER--6MBPS 15.0
PHY802.11b-TX-POWER-11MBPS 15.0
PHY802.11b-RX-SENSITIVITY--1MBPS -93.0
PHY802.11b-RX-SENSITIVITY--2MBPS -89.0
PHY802.11b-RX-SENSITIVITY--6MBPS -87.0
PHY802.11b-RX-SENSITIVITY-11MBPS -83.0
PHY802.11-ESTIMATED-DIRECTIONAL-ANTENNA-GAIN 15.0
PHY-RX-MODEL PHY802.11b
Channels the radio is capable of listening to.
PHY-LISTENABLE-CHANNEL-MASK 1
Channels the radio is currently listening to. Can be changed during run time.
PHY-LISTENING-CHANNEL-MASK 1
PHY-TEMPERATURE 320.0K
PHY-NOISE-FACTOR 10.0
ANTENNA-MODEL OMNIDIRECTIONAL
ANTENNA-GAIN 0.0
ANTENNA-HEIGHT 1.5
ANTENNA-EFFICIENCY 0.8
ANTENNA-MISMATCH-LOSS 0.3
ANTENNA-CABLE-LOSS 0.0
ANTENNA-CONNECTION-LOSS 0.2

MAC Protocol:
MAC-PROTOCOL MACDOT11
MAC-DOT11-DIRECTIONAL-ANTENNA-MODE NO
MAC-DOT11-SHORT-PACKET-TRANSMIT-LIMIT 7
MAC-DOT11-LONG-PACKET-TRANSMIT-LIMIT 4

MAC-DOT11-RTS-THRESHOLD 0
MAC-DOT11-ASSOCIATION NONE
MAC-DOT11-IBSS-SUPPORT-PS-MODE NO
MAC-PROPAGATION-DELAY 1US
PROMISCUOUS-MODE YES

ATM Layer2
ATM Layer2
ATM-LAYER2-LINK-BANDWIDTH 111200
ATM-LAYER2-LINK-PROPAGATION-DELAY 10MS
ATM-RED-MIN-THRESHOLD 5
ATM-RED-MAX-THRESHOLD 15
ATM-RED-MAX-PROBABILITY 0.02
ATM-RED-SMALL-PACKET-TRANSMISSION-TIME 10MS
ADAPTATION-PROTOCOL AAL5
ATM-LOGICAL-SUBNET-CONFIGURED NO
ATM-STATIC-ROUTE NO
ATM-CONNECTION-REFRESH-TIME 25M
ATM-CONNECTION-TIMEOUT-TIME 2M
ARP-ENABLED NO
NETWORK-PROTOCOL IP
IP-ENABLE-LOOPBACK YES
IP-LOOPBACK-ADDRESS 127.0.0.1
CERTIFICATE-ENABLED NO
EAVESDROP-ENABLED NO
IP-FRAGMENTATION-UNIT 2048
IP-QUEUE-NUM-PRIORITIES 3
IP-QUEUE-PRIORITY-INPUT-QUEUE-SIZE 50000
DUMMY-PRIORITY-QUEUE-SIZE NO
IP-QUEUE-PRIORITY-QUEUE-SIZE 50000
DUMMY-PRIORITY-WISE-IP-QUEUE-TYPE NO
IP-QUEUE-TYPE FIFO
ECN NO
IP-QUEUE-SCHEDULER STRICT-PRIORITY

<u>Routing Protocol:</u>

DUMMY-ROUTING DYNAMIC
ROUTING-PROTOCOL BELLMANFORD
OSPFv3-ADDITIONAL-PARAMETERS NO
HSRP-PROTOCOL NO
IP-FORWARDING YES
STATIC-ROUTE NO
DEFAULT-ROUTE YES
DEFAULT-ROUTE-FILE Part1.routes-default

Microwave Configuration:

MPLS-PROTOCOL NO

Transport Layer

TCP LITE
TCP-USE-RFC1323 NO
TCP-DELAY-ACKS YES
TCP-DELAY-SHORT-PACKETS-ACKS NO
TCP-USE-NAGLE-ALGORITHM YES
TCP-USE-KEEPALIVE-PROBES YES
TCP-USE-PUSH YES
TCP-MSS 512
TCP-SEND-BUFFER 16384
TCP-RECEIVE-BUFFER 16384

Traffic and Status
Application Layer:
APP-CONFIG-FILE Part1.app
RTP-ENABLED NO
PACKET-TRACE NO
ACCESS-LIST-TRACE NO

Statistics:
APPLICATION-STATISTICS YES
TCP-STATISTICS YES
UDP-STATISTICS YES
ROUTING-STATISTICS YES
ICMP-STATISTICS NO
IGMP-STATISTICS NO
EXTERIOR-GATEWAY-PROTOCOL-STATISTICS YES
NETWORK-LAYER-STATISTICS YES
QUEUE-STATISTICS YES
INPUT-QUEUE-STATISTICS NO
SCHEDULER-STATISTICS YES
INPUT-SCHEDULER-STATISTICS NO
MAC-LAYER-STATISTICS YES
PHY-LAYER-STATISTICS YES
BATTERY-MODEL-STATISTICS NO
ENERGY-MODEL-STATISTICS YES
MOBILITY-STATISTICS NO
MPLS-STATISTICS NO
MPLS-LDP-STATISTICS NO

RSVP-STATISTICS NO
SRM-STATISTICS NO
DIFFSERV-EDGE-ROUTER-STATISTICS NO
QOSPF-STATISTICS NO
ACCESS-LIST-STATISTICS NO
POLICY-ROUTING-STATISTICS NO
ROUTE-REDISTRIBUTION-STATISTICS NO
SIGNALLING-STATISTICS NO
RTP-STATISTICS NO
GSM-STATISTICS NO
CELLULAR-STATISTICS NO
MOBILE-IP-STATISTICS NO
ATM-SCHEDULER-STATISTICS NO
ATM-LAYER2-STATISTICS NO
ADAPTATION-LAYER-STATISTICS NO

Node Specific:

Device properties:

Router Specs
DUMMY-ROUTER-TYPE USER-SPECIFIED
DUMMY-PARAM NO

Router Configuration Specs:

Node Orientation:
AZIMUTH 0
ELEVATION 0

Parallel Properties:
PARTITION 0

STK
STK
DUMMY-STK-ENABLED NO

User Behavior Model:

User Behavior Model:
DUMMY-UBEE-ENABLED NO

LLC Configuration:

LLC-ENABLED NO

Subnet ID 1

SUBNET N8-192.0.0.0 { 1 thru 11 } 742.96 813.38 0.0
[N8-192.0.0.0] NODE-ICON C:\qualnet\4.5\scenarios\user\Part1\wireless-subnet.png
[N8-192.0.0.0] PHY-MODEL PHY802.11b
[N8-192.0.0.0] PHY802.11-AUTO-RATE-FALLBACK NO
[N8-192.0.0.0] PHY802.11-DATA-RATE 2000000
[N8-192.0.0.0] PHY802.11b-TX-POWER--1MBPS 15.0
[N8-192.0.0.0] PHY802.11b-TX-POWER--2MBPS 15.0
[N8-192.0.0.0] PHY802.11b-TX-POWER--6MBPS 15.0
[N8-192.0.0.0] PHY802.11b-TX-POWER-11MBPS 15.0
[N8-192.0.0.0] PHY802.11b-RX-SENSITIVITY--1MBPS -93.0
[N8-192.0.0.0] PHY802.11b-RX-SENSITIVITY--2MBPS -89.0
[N8-192.0.0.0] PHY802.11b-RX-SENSITIVITY--6MBPS -87.0
[N8-192.0.0.0] PHY802.11b-RX-SENSITIVITY-11MBPS -83.0
[N8-192.0.0.0] PHY802.11-ESTIMATED-DIRECTIONAL-ANTENNA-GAIN 15.0
[N8-192.0.0.0] PHY-RX-MODEL PHY802.11b
[N8-192.0.0.0] PHY-LISTENABLE-CHANNEL-MASK 1
[N8-192.0.0.0] PHY-LISTENING-CHANNEL-MASK 1
[N8-192.0.0.0] PHY-TEMPERATURE 290.0
[N8-192.0.0.0] PHY-NOISE-FACTOR 10.0
[N8-192.0.0.0] ANTENNA-MODEL-CONFIG-FILE-SPECIFY NO
[N8-192.0.0.0] ANTENNA-MODEL OMNIDIRECTIONAL
[N8-192.0.0.0] ANTENNA-GAIN 0.0
[N8-192.0.0.0] ANTENNA-HEIGHT 1.5
[N8-192.0.0.0] ANTENNA-EFFICIENCY 0.8
[N8-192.0.0.0] ANTENNA-MISMATCH-LOSS 0.3
[N8-192.0.0.0] ANTENNA-CABLE-LOSS 0.0
[N8-192.0.0.0] ANTENNA-CONNECTION-LOSS 0.2
[N8-192.0.0.0] MAC-PROTOCOL MACDOT11
[N8-192.0.0.0] MAC-DOT11-DIRECTIONAL-ANTENNA-MODE NO
[N8-192.0.0.0] MAC-DOT11-STOP-RECEIVING-AFTER-HEADER-MODE NO
[N8-192.0.0.0] MAC-DOT11-SHORT-PACKET-TRANSMIT-LIMIT 7
[N8-192.0.0.0] MAC-DOT11-LONG-PACKET-TRANSMIT-LIMIT 4
[N8-192.0.0.0] MAC-DOT11-RTS-THRESHOLD 0
[N8-192.0.0.0] MAC-DOT11-ASSOCIATION NONE
[N8-192.0.0.0] MAC-DOT11-IBSS-SUPPORT-PS-MODE NO
[N8-192.0.0.0] PROMISCUOUS-MODE YES
[N8-192.0.0.0] NETWORK-PROTOCOL IP
[N8-192.0.0.0] ARP-ENABLED NO

Channel
- **Frequency : 2.4 GHz**
- **Propagation Model : Statistical**
- **Propagation Limit : -111dB**

Path-loss Model
- **Two Ray**
- **Street M- To-M**

Shadowing Model Constant
•Shadowing Mean – 4dB

Radio/ Physical Layer
- **Listenable Channel Mask : 1**
- **Listening Channel Mask : 1**
- **Temperature : 320 K**

Radio Type
- **802.11b radio**

Routing Algorithm
- **Bellman-Ford Routing Algorithm**

Interface Name	interface0
IPv4 Address	192.0.8.1
IPv4 Subnet Mask	255.255.255.0
IPv6 Address	2000:0:0:7:0:0:0:1
IPv6 subnet prefix length	64
Interface Type	DEFAULT_TYPE
Interface Number	DEFAULT_NUMBER
Is Unnumbered?	NO

Antenna Model *	Omnidirectional
• Antenna gain (dB) *	3.0
• Antenna height (m) *	1.5
• Anten (r/w) antenna gain in dB	
• Antenna mismatch loss (dB)	0.3
• Antenna cable loss (dB) *	0.0
• Antenna connection loss (dE	0.2

PHY model : PHY 802.11b
PHY- Noise Factor : 10.0

Radio Type *	802.11b Radio
• Transmission powe (r/w) PHY-MODEL	
• Transmission power 2 Mbp	15.0
• Transmission power 6 Mbp	15.0
• Transmission power 11 Mb	15.0
• Receive Sensitivity 1 Mbps	-93.0
• Receive Sensitivity 2 Mbps	-89.0
• Receive Sensitivity 6 Mbps	-87.0
• Receive Sensitivity 11 Mbp	-83.0
• Estimated directional ante	15.0

Figure 6: Summary of the Design Parameters

6. SIMULATION and RESULTS:

Various simulations have been done for various different configurations of the PAN coordinators and different graphs have been plotted against different parameters. All these graphs are simultaneously analyzed to produce a clear picture of the related parameters. The main purpose behind the simultaneous analysis of the different configurations is to form a clear picture of all the nodes usages, a general idea of the power consumption and throughput efficiency and to integrate the positives of all these into the final scenario. The four scenarios are the fundamental design scenarios possible to implement in the given design arena.

6.1 SCENARIO 1:

This forms the fundamental scenario where all the nodes are placed randomly and they are communicating with the central PAN co-coordinator. Some nodes are not involved in the process of communication and thus are left astray. They are assumed to not send relevant data at this point of time but they are connected to the wireless subnet forming the network layer for the entire scenario. The data links chosen are Constant Bit Rate (CBR) links where-in the data send is assumed to have constant rate of packet delivery. There are 100 packets of data to be send where-in each packet consists of 512 bytes of data. So 6 nodes are sending the data and the central PAN coordinator is receiving all of it. Comparing it to the actual design scenario (figure no.) we find that it is actually the PAN structures formed by the nodes numbered in the design with the central receiver being the PAN coordinator. This is a typical star network.

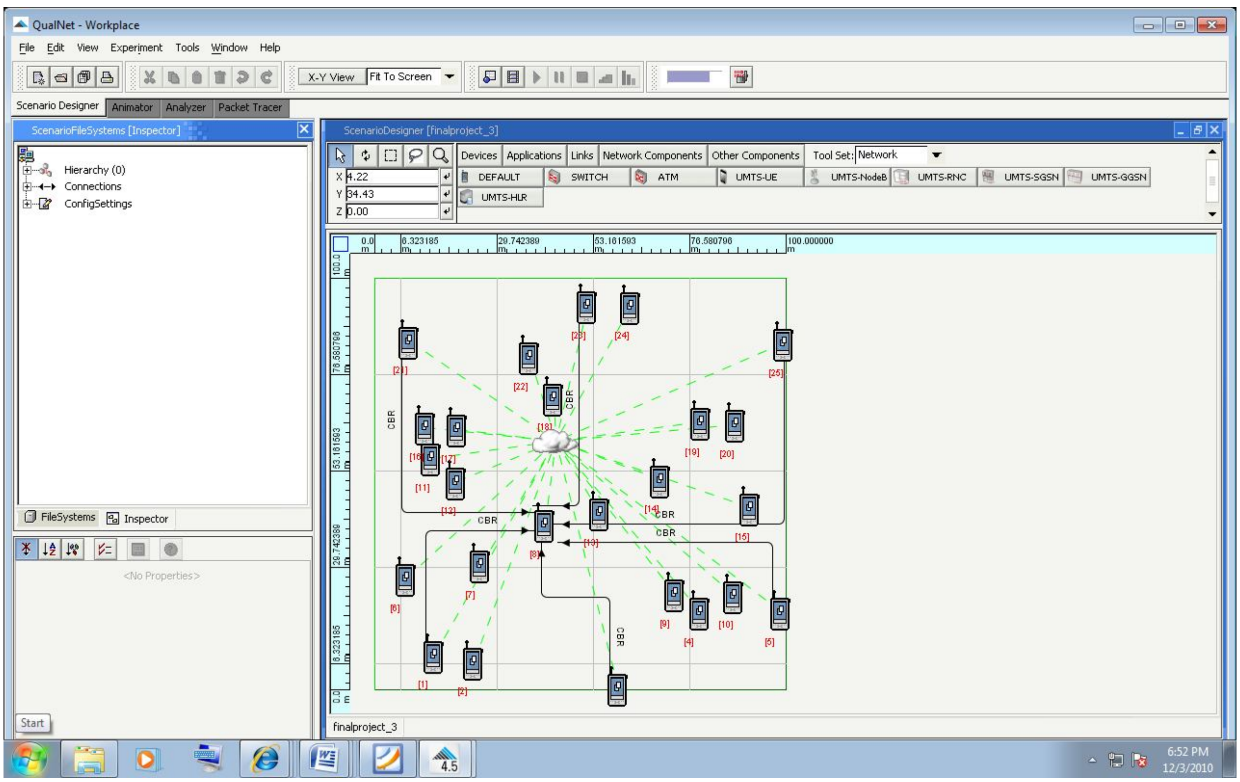

Figure 7: Scenario1

The simulation is made to run for 300 seconds. Each of the 6 nodes on a CBR link to the server (node 8) is made to send an equal number of packets to the PAN coordinator. The size of each packet is 512 bytes. The MAC protocol and the Radio Protocols are adjusted to the Zigbee standards of 802.15.4 Radio. The sensor node transmission power is varied from -3dBm to 3 dBm. The results shown are for 0 dBi power transmission. The channel properties are default set at 2.4 MHz freq for statistical propagation model for a propagation limit of -111dBm. The beacon order is varied from 3 to 5.

The various levels of Analysis:

- Application level
- Transport level
- Network Level
- MAC Level
- SSCS Level
- Physical Level

Application level analysis:

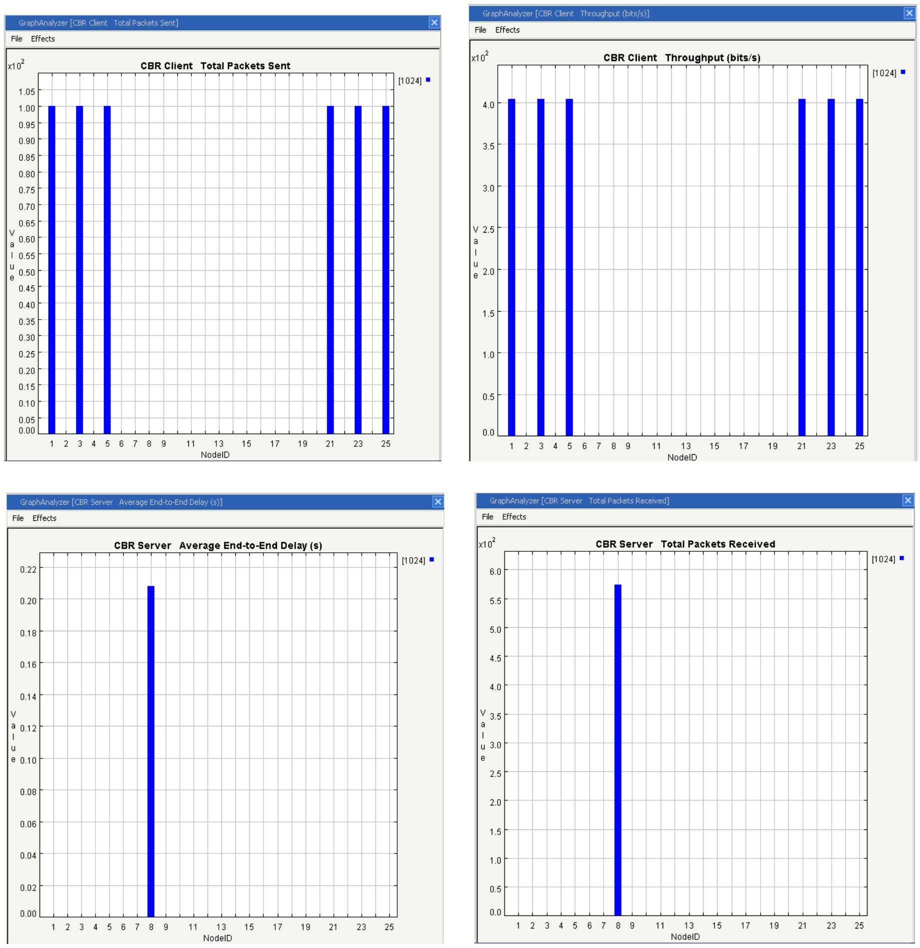

Figure 8 :Application level plots of Scenario 1

The percentage packet delivery can thus be calculated as:

(Total packets Delivered / Total packets sent) * 100

(5.74/6) * 100 = 96.7%

The variation of the *Sensor node transmission power* and the *Beacon Order* play a vital role in the above factor. The *Superframe Order* also effects directly apart from other parameters that have an indirect effect on the ratio. The power was made to increase to 3 dBm and the Beacon order was fixed at 3 to achieve the above calculated figure.

Network level analysis:

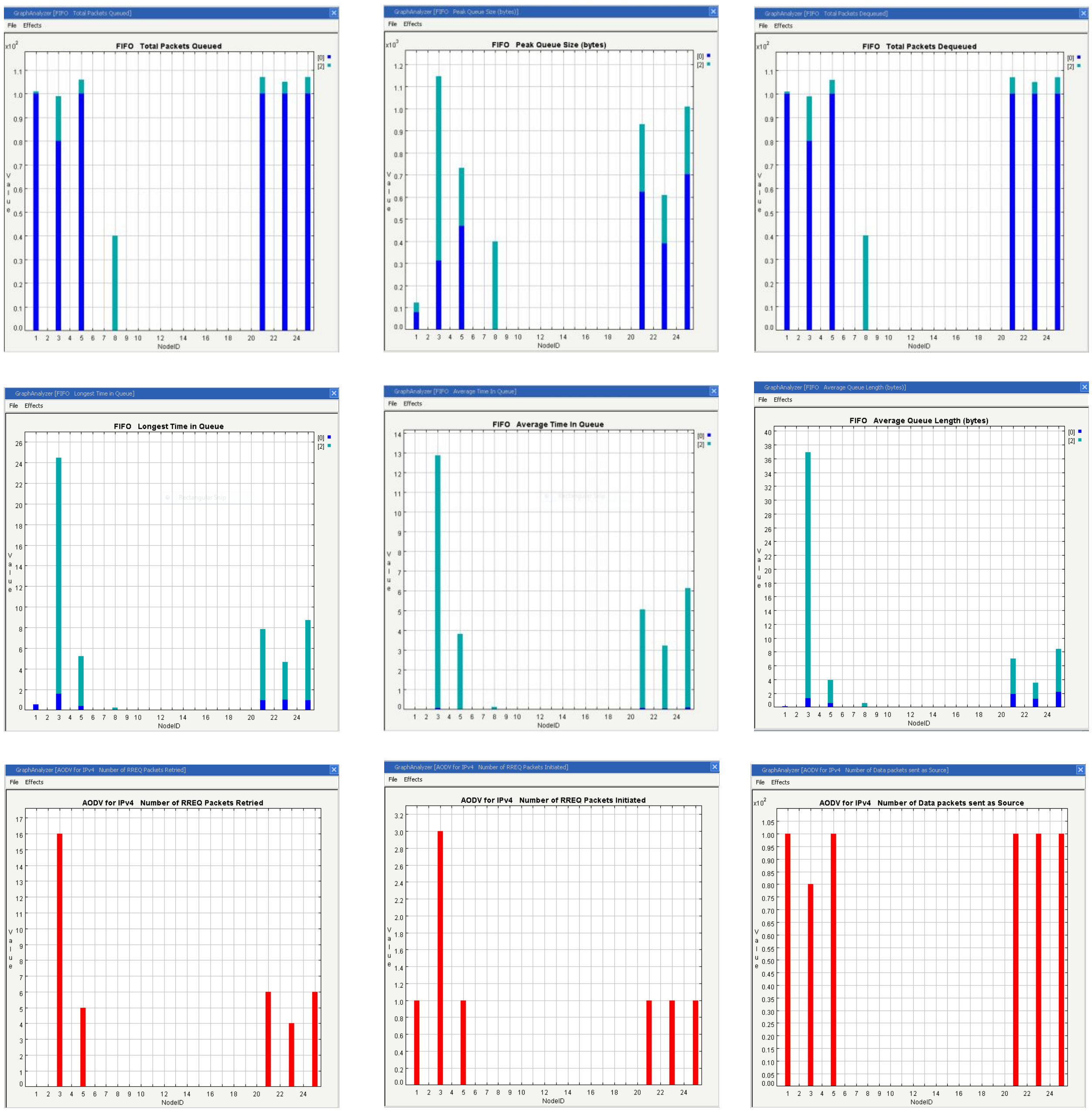

Figure 9: Network level plots of Scenario 1

The graphs clearly show that the queue time increases as the distance of the node form the PAN coordinator increases. As expected, the PAN coordinator receives more bytes than sent by it. The beacons sent by the clients are mostly hello broadcasts. The Ad hoc On-Demand Distance Vector (AODV) Routing used in the scenario carries out transmission only when there is a need, else it sends the node to an idle state where power conservation occurs.

MAC Level Analysis:

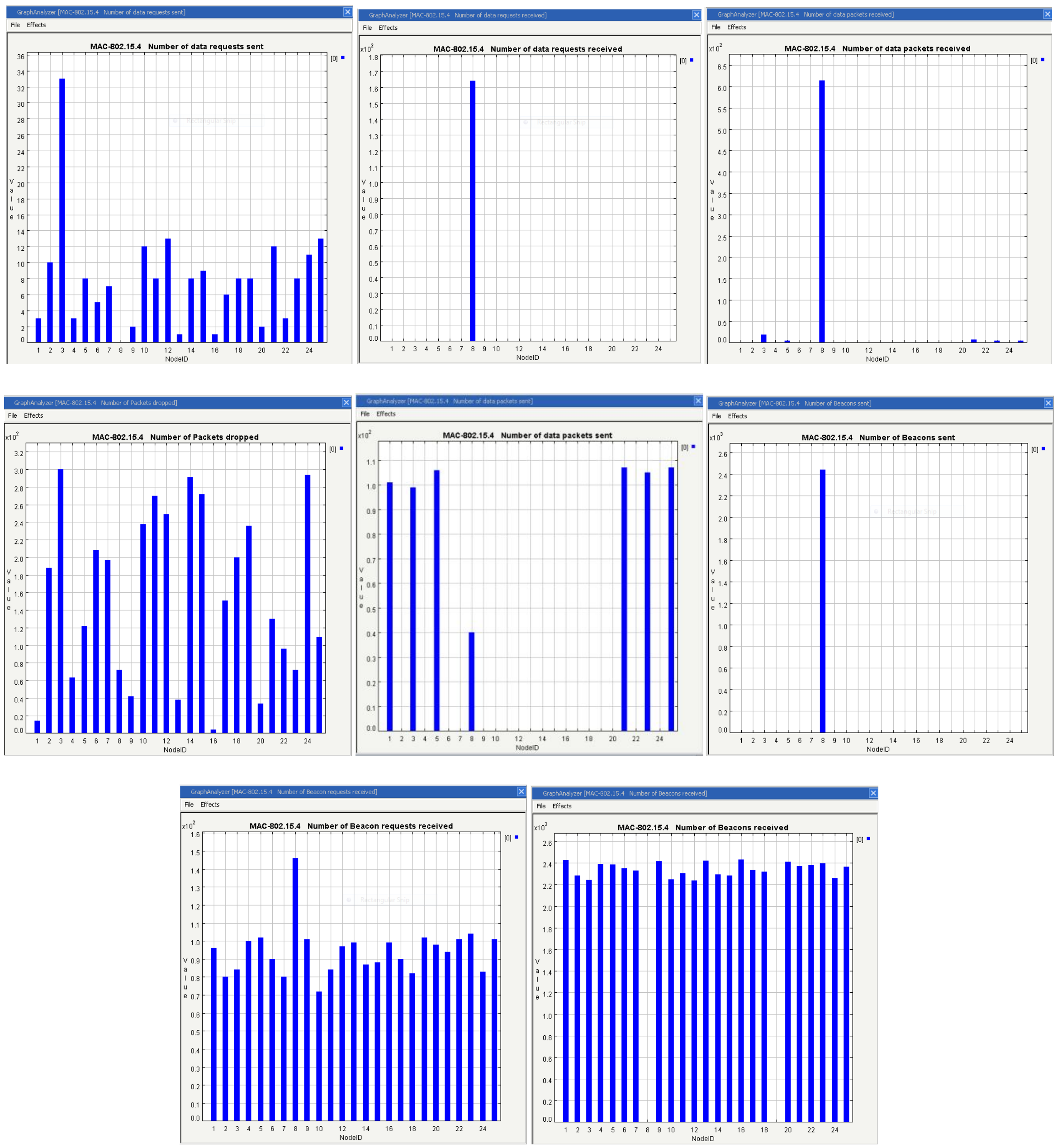

Figure 10: MAC level plots of Scenario 1

The graphs above depict the transmission and reception of signals that occurs at the Media Access Control (MAC) Layer. This directly reflects the trans- reception happening at the physical layer of the Network. This project is mostly concerned with the application level communication and thus shall not be going into deep analysis of the physical layer. But the representation helps in knowledge and confirmation on the actual signal transmission.

6.2 SCENARIO 2:

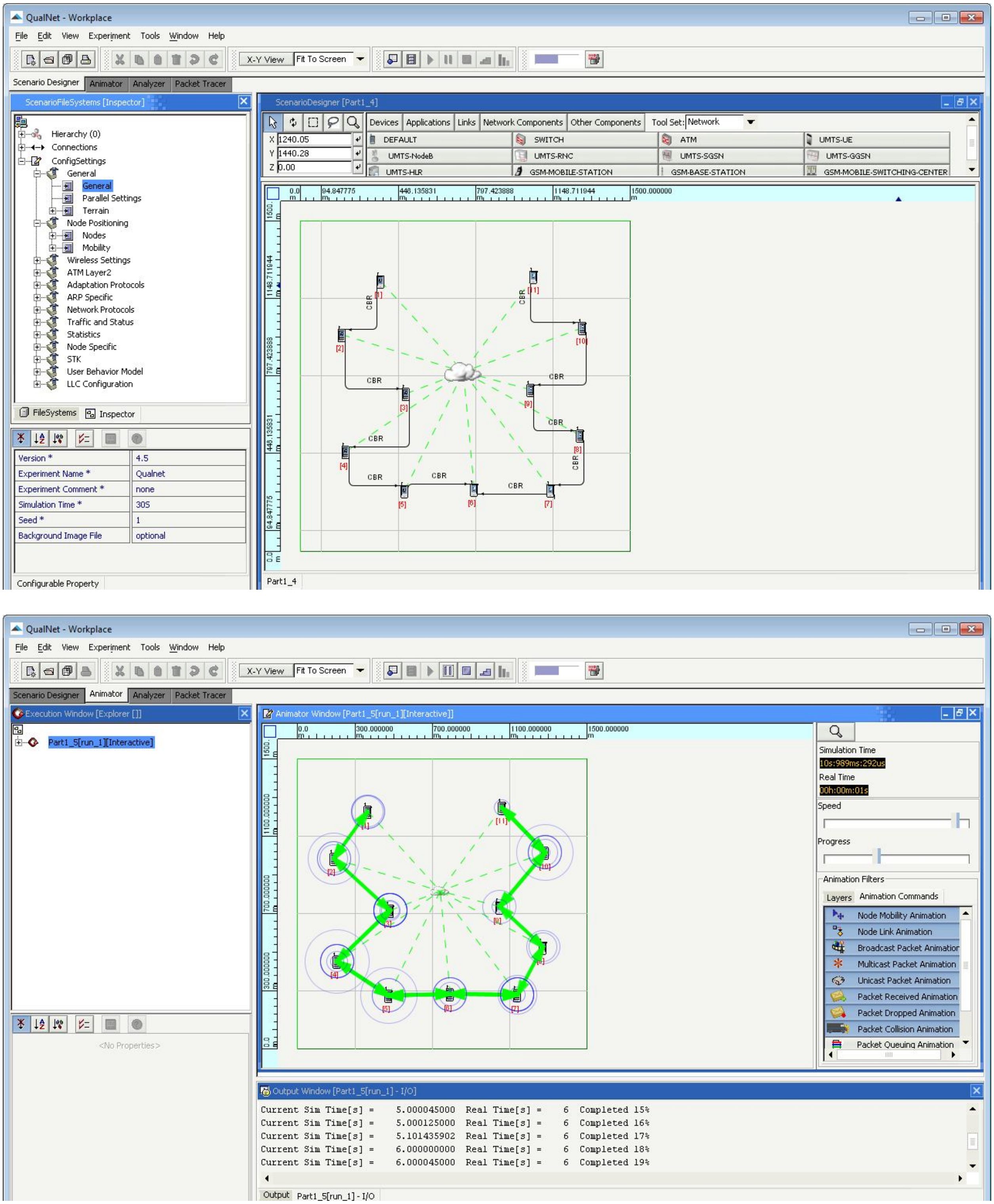

Figure 11: Scenario 2 and its simulation in *Qualnet*

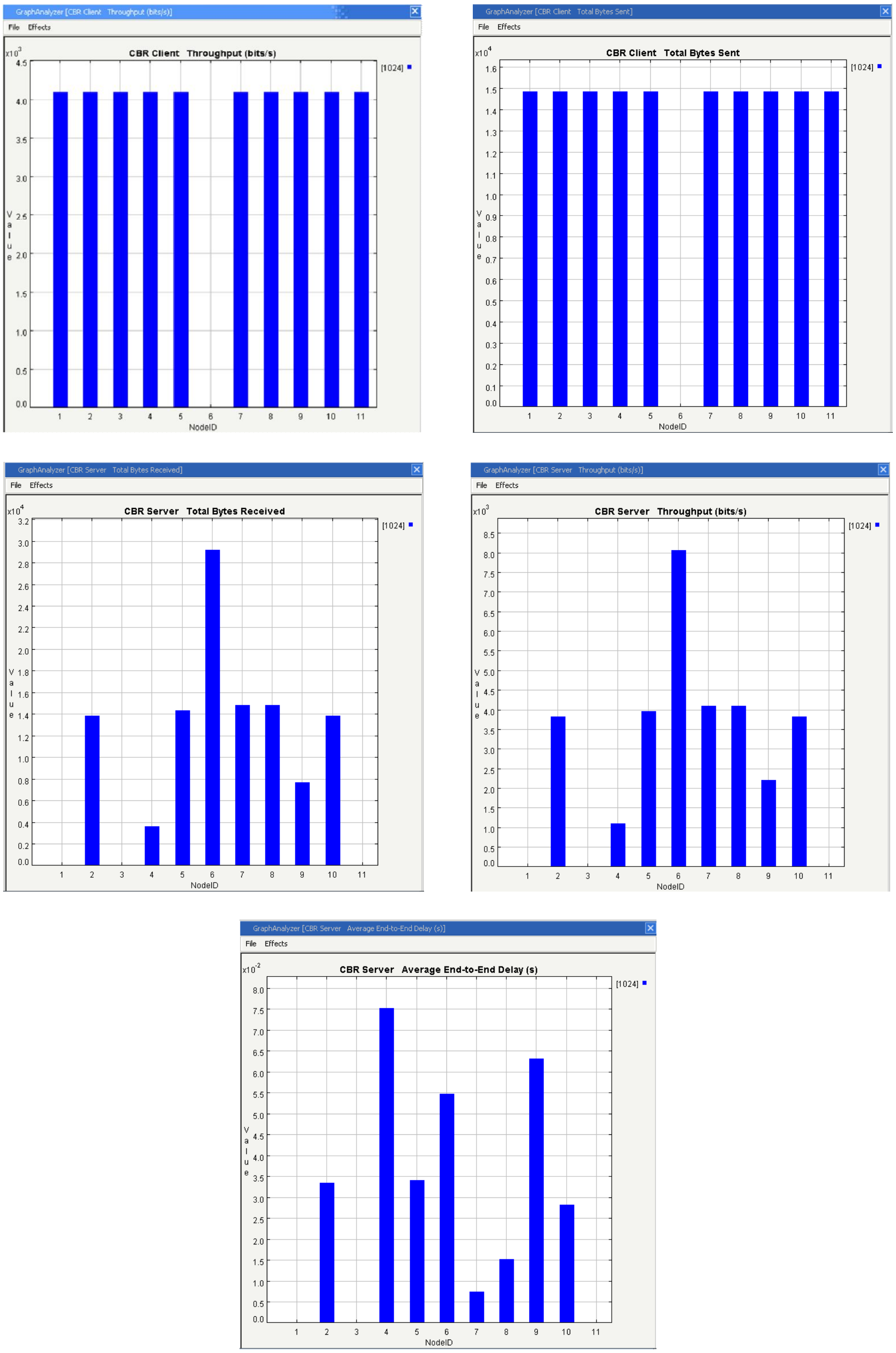

Figure 12: Output plots of Scenario2

As seen from the graphs all the nodes 1, 2, 3, 4, 5, 7, 8, 9, 10 and 11 are kept busy and seen to be busy sending the mandated number of packets of data and the related values of throughput show that there is a very limited loss of the packets of data. The given values of data to be send through the PAN coordinators are 100 packets each of 512 bytes. The graphs show a perfect alignment with the expected results with respect total bytes sent and the throughput.

The receiving end shows variations as the data is transferred through the nodes through multiple hopping and is finally received at the node 6. As seen apart from node 1, 3 and 11 all are involved actively in the process of data reception. This is due to the queuing and hopping used for the purpose. This shows that a linear hopping technique is going to keep the nodes busy and is going to be demanding on the already power scarce nodes.

As expected the average end to end delay is maximum for the nodes that are in the middle of the hopping and which have accounted for maximum reception. An exact adaptation of such a scenario would do injustice to the nodes and their power requirements.

The above figures convey this very accurately that the physical layer is actively found to participate in the signal transmission and thus we can safely infer that the scenario is ready for implementation.

6.3 SCENARIO 3:

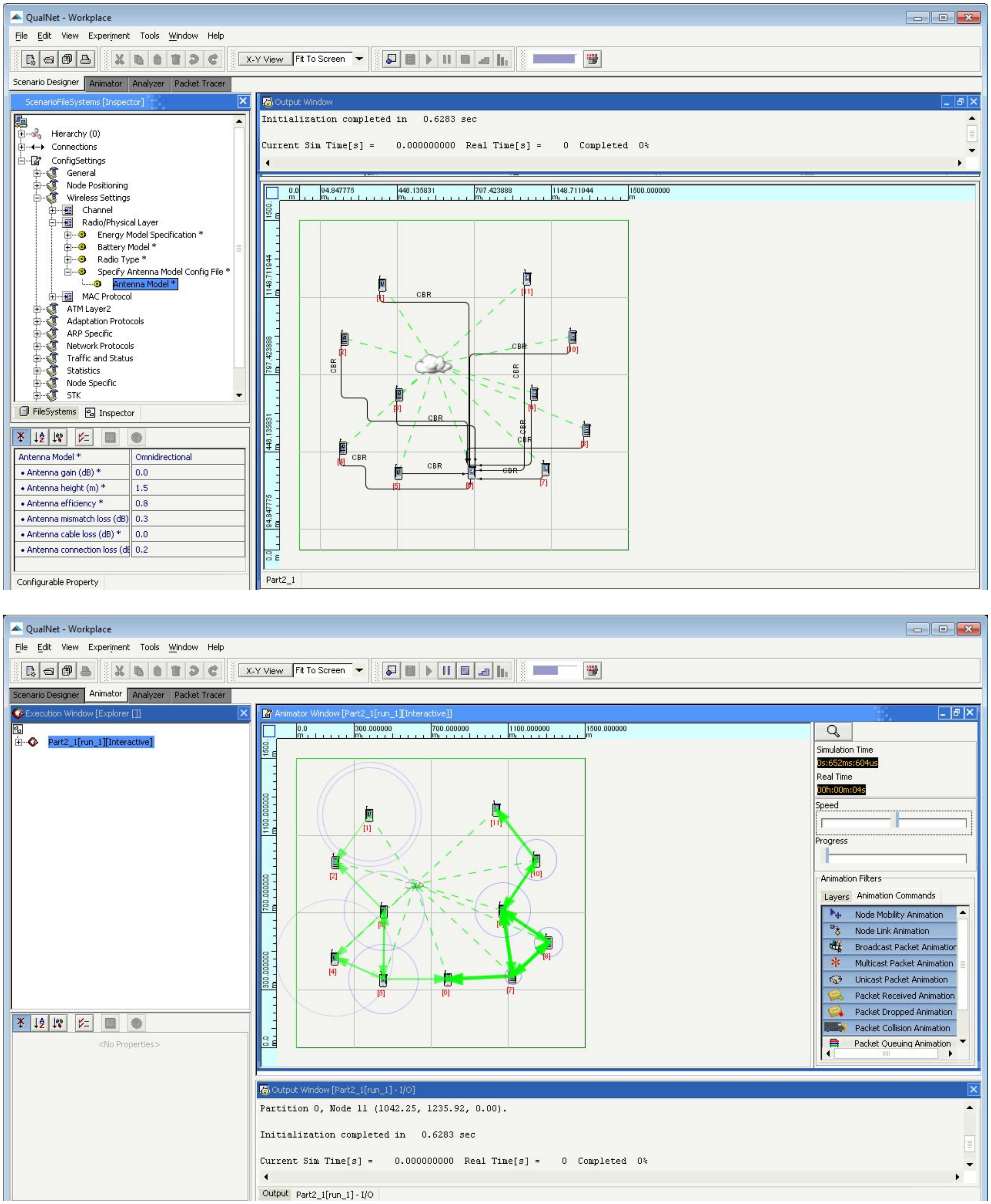

Figure 13: Scenario3 and its simulation in *Qualnet*

This scenario is an extreme case in which all the PAN coordinators are sending the data directly to the base station through the CBR links. Although the results suggest better accuracy and more efficiency, this scenario is practically in-feasible, since the central coal block (As shown on figure(x)) would intervene with a line of sight communication.

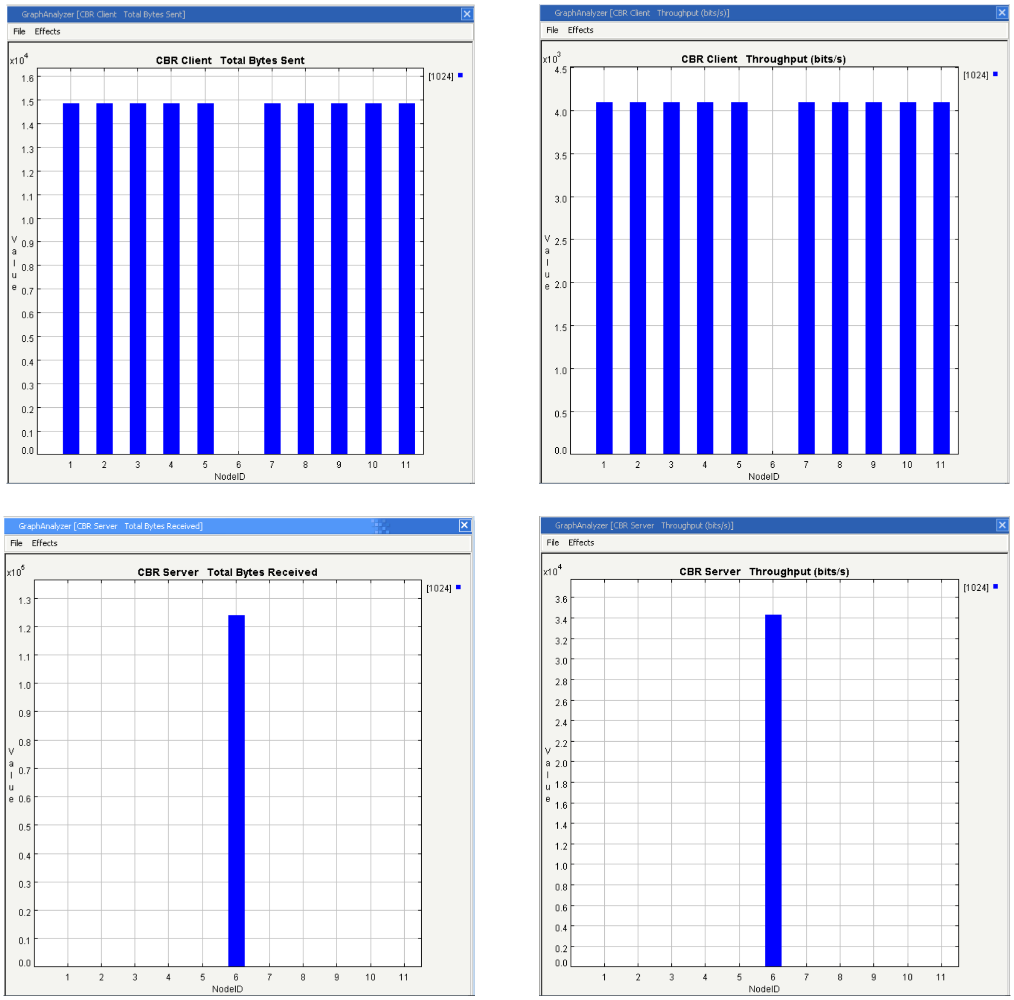

Figure 14: Output plots for Scenario3

As expected the results show data transmission directly from all the nodes to the central PAN coordinator. The throughput is also 100% accurate with all the nodes sending {4.2*exp (10, 3)} bits per second. The node-6 had been assigned the role of the receiver and it shows results as expected i.e. receiving the data transmitted by all the PAN coordinators.

6.4 SCENARIO 4:

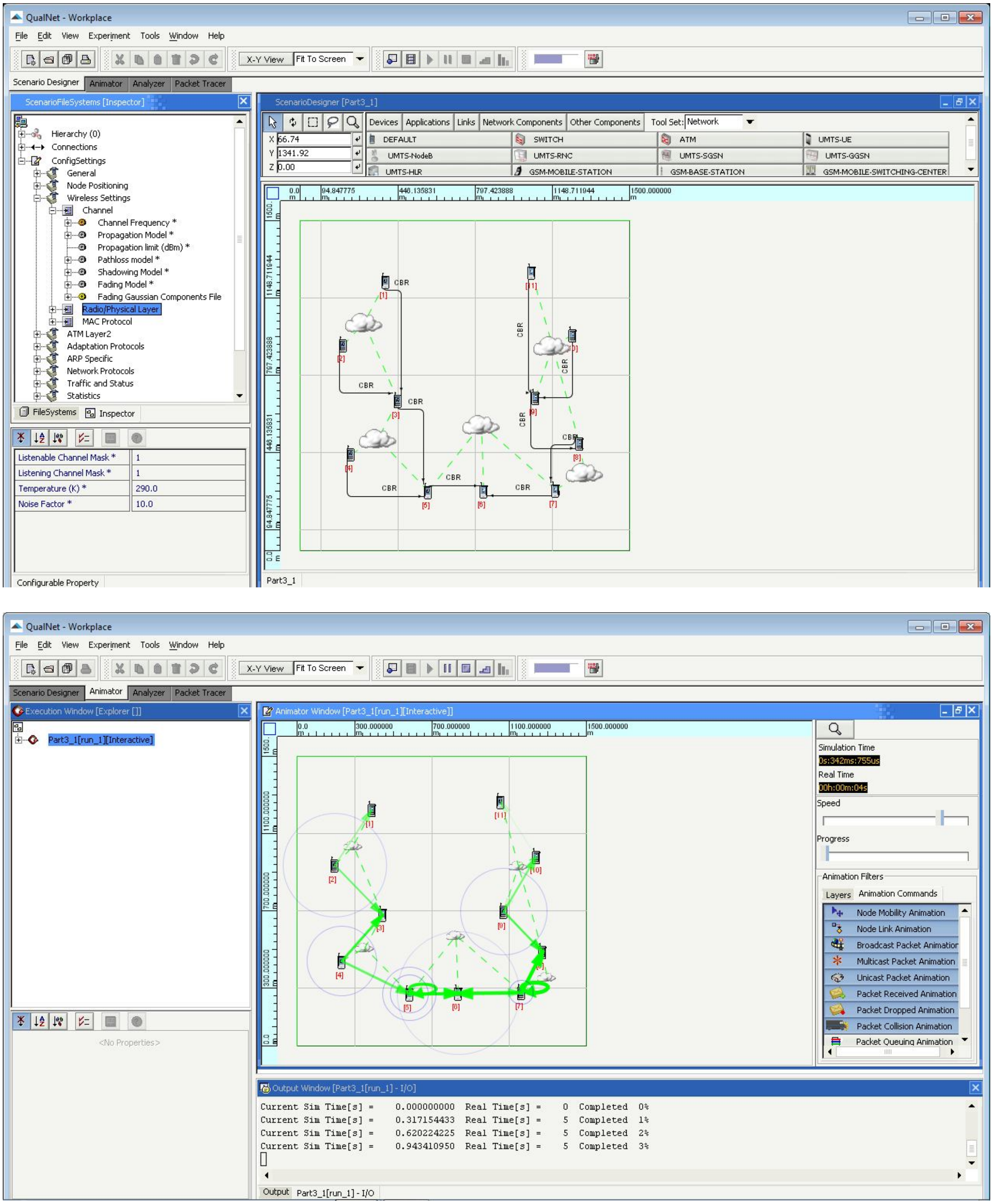

Figure 15: Scenario4 and its simulation in *Qualnet*

This scenario is modified version of the two earlier scenarios. Here we use a combination of both Multi-hopping and direct transmission to arrive at an optimized result.

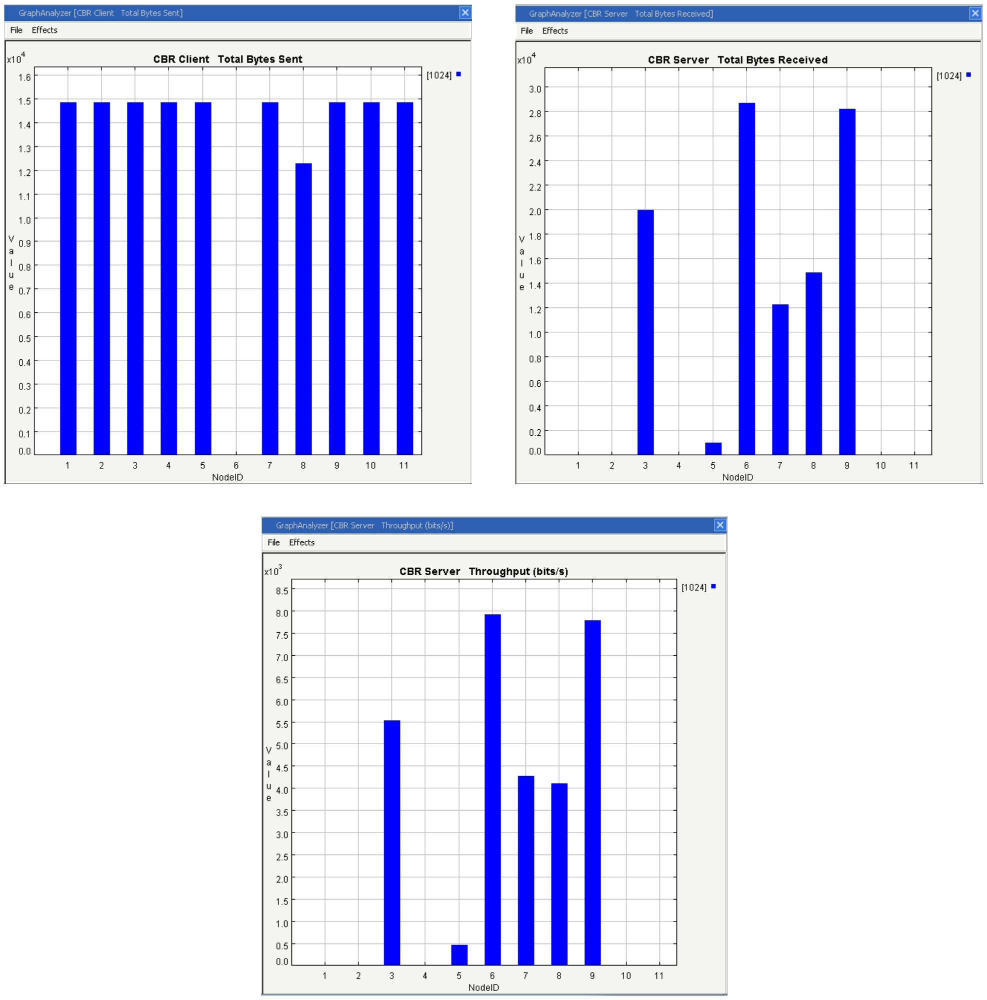

Figure 16: Output plots for Scenario4

As seen from the above graphs though the PANs have been transmitting the same mandated amount of data but there is a change in the reception graphs. We find that the occupancy of the nodes with respect to the transmission and throughput to be reduced to a great extent thus suggesting a much better power efficiency.

6.5 The FINAL SCENARIO:

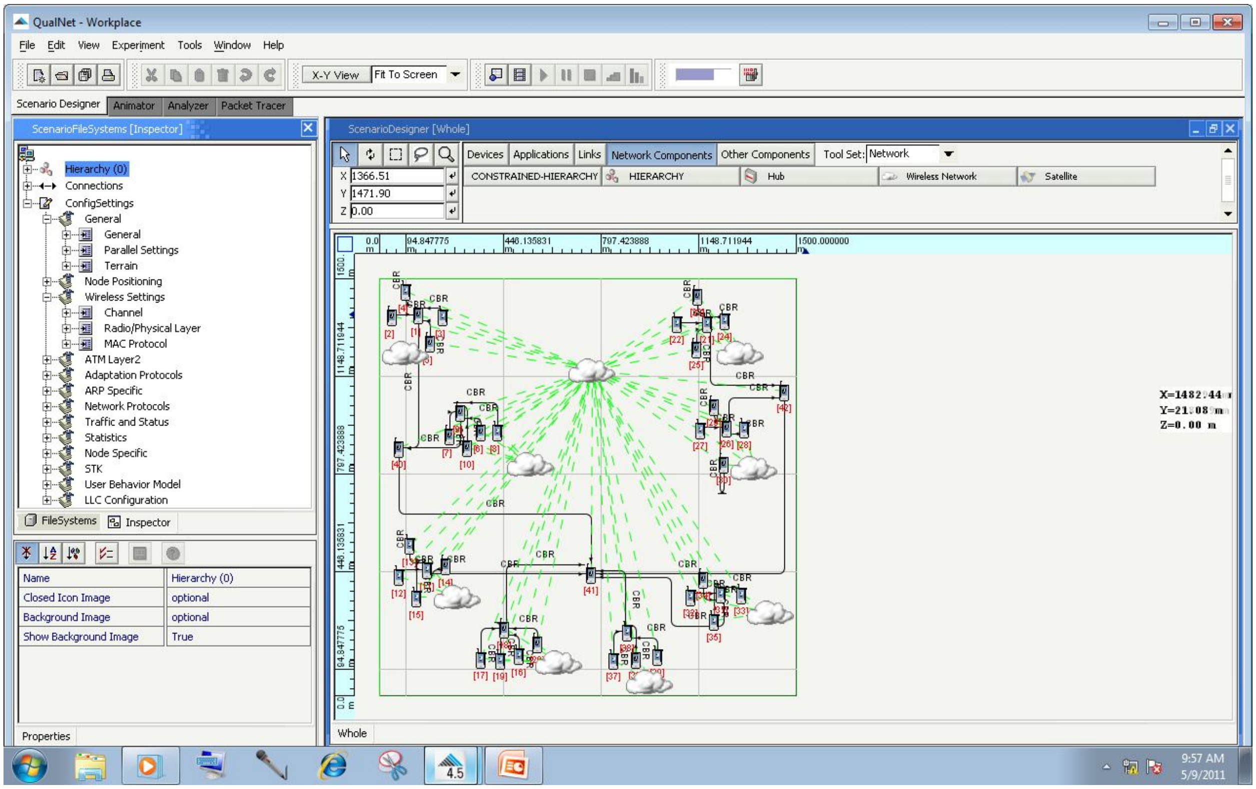

Figure 17: Scenario4

This scenario has been designed taking into account all the best points of the last designed scenarios. Each PAN coordinator has been assigned with 3-4 RFDs around it which are communicating only with it using the CBR links. There are separate wireless subnets for each of the PANs and a wireless subnet for the entire scenario. Each PAN coordinators collects data from its group sensors and then relays it to the base station for reception. The node-41 is the base station which is the only node that doesn't transmit any data but rather finally receives all of them through the PAN coordinator hopping configuration.

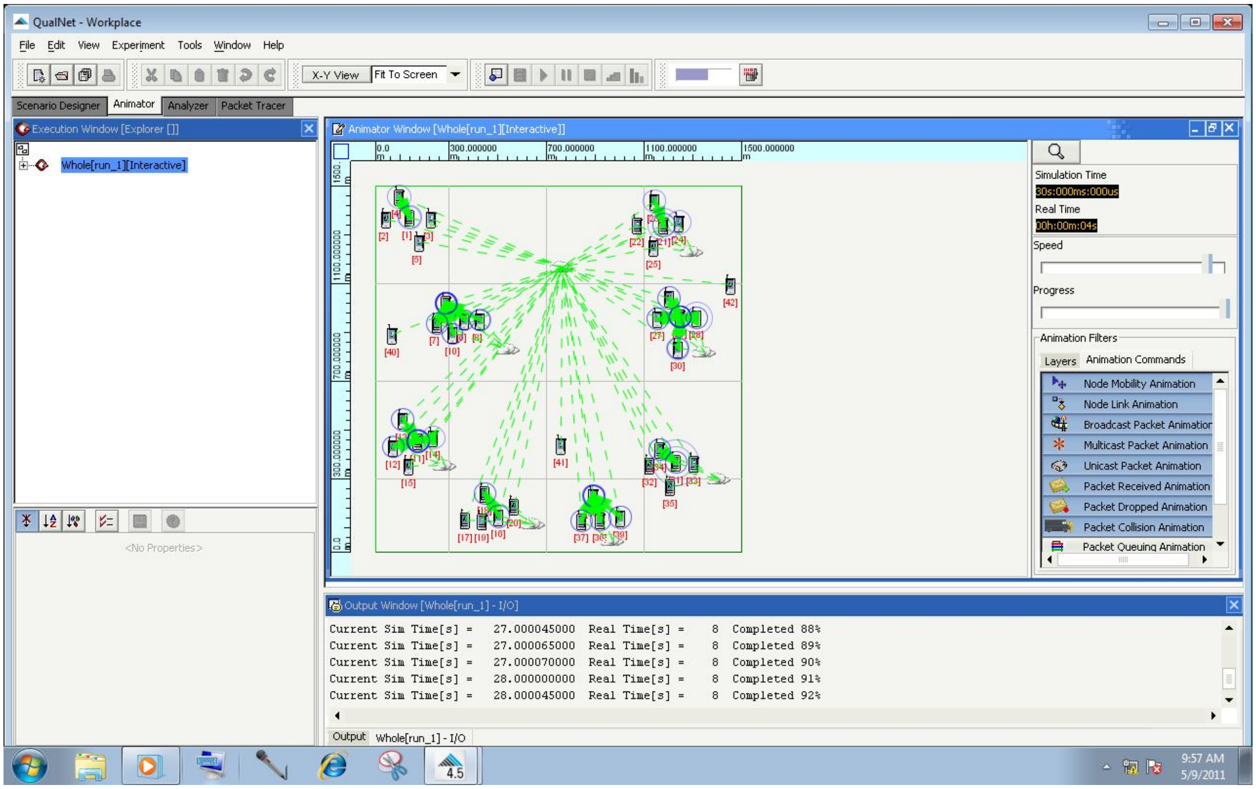

Figure 18: *Qualnet* Simulation of the Final Scenario

The simulation was run for 0.04s which corresponds to an actual simulation time of 30s. The antenna heights of the sensor nodes was kept at 0.5m and the PAN coordinator antennas were kept at 1.5m this has been purposefully done to ensure limited data transfer for the PANs where in the sensors send data to its PAN coordinators only and not to any other PAN. This would ensure data integrity, better signal transmission and at the same time doing justice to the power constraint.

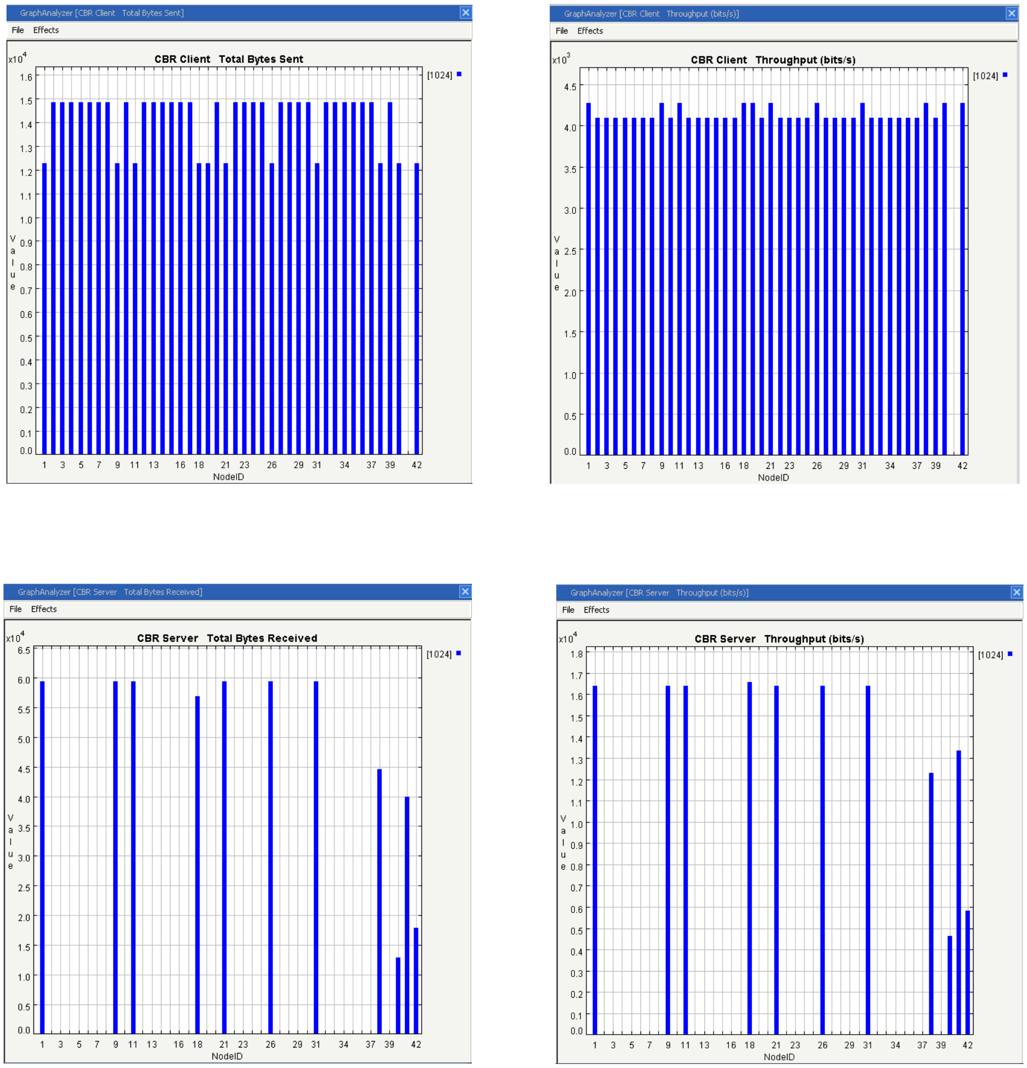

Figure 19: Output plots for Scenario4

As expected the graphs show that all the nodes have been equally engaged in sending data but are differentially engaged in receiving it. The reason is that the multiple hopping algorithms used for the PAN coordinators reduces the time required in stalking up the data and thus we see very few nodes have a net reception. The throughput tallies accordingly.

7. CONCLUSION:

Through the various scenario plots it becomes clear that a complicated combination of star and mesh networks can only produce the required results. Therefore the final scenario is a combination of the Personal Area Networks (PAN) and a mesh structure connecting the PAN coordinators. The main concerns have been the optimal use of the nodes. These nodes have to be very much constrained in terms of power usage. So they have limited functionality. The sensor had to be RFDs (Reduced Functional Devices) while only a very few nodes could be assigned the status of FFDs (Full Functional Devices). There a variety of hopping, star and mesh networks were simultaneously simulated for a comparative analysis. The design parameters were kept in close correspondence to the actual mine parameters. The antenna heights and the data rates were also varied to judge the relative efficiency. The mine scenario used as a reference for all the scenarios is typical approximation of a 3 tunnel structure with a central coal block. This can be extrapolated to the entire mine assuming a multiple repetition. The final design is a combined effort after the analysis of the strengths of all the scenarios and can be confidently assumed to work accurately on actual implementation.

8. CITATIONS and REFERENCES:

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