LOCAL UPDATE ROUTING USING HIERARCHICAL WPANS IN WIRELESS UNDERWATER SENSOR NETWORKS

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Abstract

The developments of micro and nano sensors lead the sensor networking technology to be used in all kinds of study. In underwater communications and study, wireless sensor network plays a major role. One among the characteristics of underwater communications is propagation delay that affects the network throughput. To increase the throughput, here we propose the local update routing. In this technique the end to end delay is minimized by using hierarchical WPANs. This is proved with reduced latency using Omnet++ simulator.

Keywords: latency; MiXiM framework, network throughput.

1. Introduction

Wireless Underwater Sensor Network (UWSN) consists of many underwater sensors. The sensor nodes are deployed below the sea surface. After deployment they organize themselves to form a network. They collect the data and forward the data to the sink node or to the control center present in the sea surface. Data transmission is carried out either by sound or by radio or by light. Normally acoustic transmission is selected compared to electromagnetic and optical transmissions because of its low power loss and high effective range.

Some of the major applications of underwater sensor wireless networks are oceanography, marine biology, deep-sea archaeology, seismic predictions, pollution detection and oil/gas field monitoring. Also they are used in underwater natural resource discovery, anti-submarine military mission, hurricane disaster recovery and lost treasure detection [1], [2], [3], [6].

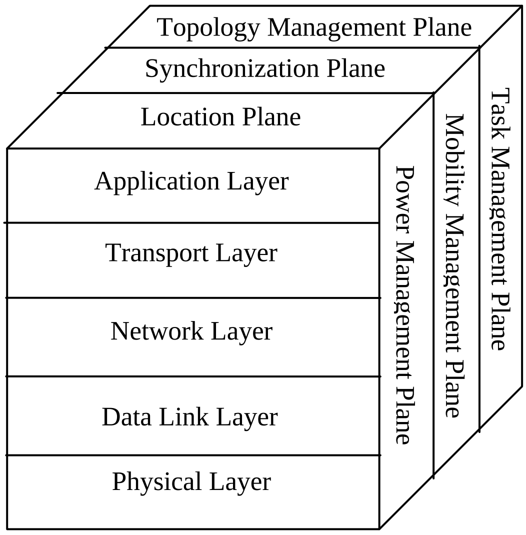

Fig.1. Logical layer description of a underwater sensor node stack

Logical layer description of a single underwater sensor node stack is shown in Fig.1 Due to limited battery power and limited bandwidth the design of underwater sensor network becomes critical. Also multi-path propagation and fading affects the underwater channel which in turn increase the complexity of the design. Moreover, compared to terrestrial wireless sensor network, propagation delay in underwater is greater than five orders of magnitude. This again gives more challenges in the design.

In underwater sensor networks usually batteries cannot be recharged as well as solar energy cannot be exploited. The basic difference between terrestrial and underwater sensor networks is the communication medium. Similar to terrestrial sensor network the sensor nodes in the underwater sensor network are prone to failure. Major reason for the failure is because of fouling and corrosion. Due to the more complex underwater transceivers and the necessary hardware protection in the underwater environment, the underwater sensors become more expensive. Due to the cost of the network and the challenges in the deployment make the deployment usually to be sparse. Compared to terrestrial network the power required in underwater sensor network is more because of longer distance communication and compensation at receivers by complex signal processing [9], [10].

The underwater sensor networks can be defined with wireless private area networks. In the IEEE 802.15.4 Low Rate-Wireless Personal Area Network (LR-WPAN) [7] two different types of devices are defined. They are full function device (FFD) and a reduced function device (RFD). A FFD serves as a PAN coordinator and it has the ability to interact with any other device. The RFD has the ability to talk only with the FFD node. Also the LR-WPAN standard support a star and a peer-to-peer network topologies. In star network topology, the communication occurs only between end devices and a single central controller and which manages the entire PAN. In peer-to-peer network topology, a node may only talk to its parent or children nodes.

2. Related Work

Unlike the sensors of terrestrial WSN, UWSN sensor cannot use solar energy to recharge the battery and also it is very difficult to replace the sensors after deployment. The solution for this problem is either to generate energy by the sensors themselves or to use efficient routing protocol and communication method [4], [5]. Even though some of the authors addressed the same problem, here we proposed the new routing algorithm which is efficient enough to reduce the latency to improve the network throughput.

Simulating a sensor network found to be a problem and is solved by some of the authors with NS-2 or matlab. But significant amount of research results are coming out using omnet++ network simulator. Very few works addressed about the aquasim for UWSN. In our previous work [8] we presented about nodes mobility and about the routing methods to increase the lifetime using omnet++ network simulator.

3. System Description

The underwater sensor network is formed with a single static sink node and many underwater sensor nodes. Sink is placed in the sea surface level. Two types of underwater sensor nodes were used. One type is a FFD and another is RFD. In the deepest part of sea many RFDs are deployed with few FFDs maintaining the ratio of 5:1. Above that level only FFDs are deployed in different depths. Description of deployment is depicted in fig.2.

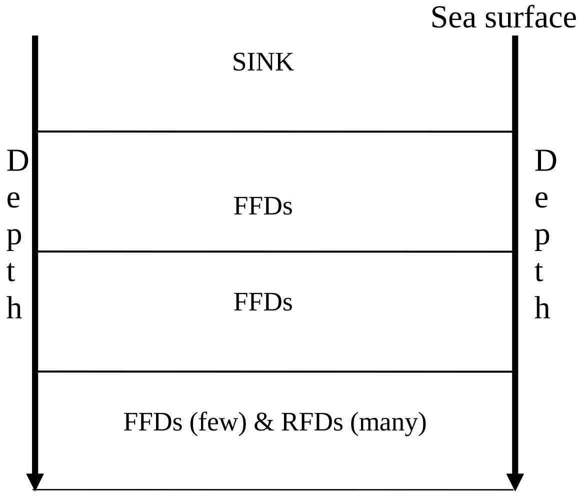

Fig.2. Description of deployment

Since FFD acts like a PAN coordinator, initially it fixes the member nodes which are nothing but RFDs. The data sensed by the RFD-sensor nodes are directly given to the FFD-sensor node. At FFDs the received and sensed data are aggregated. These FFDs forward the aggregated data to the upper FFDs and finally to the sink. Thus the network follows hierarchical nature of WPANs. The objective of the network is to collect data from the underwater in different sea depth levels. Due to the challenges in the design it is taken care to save energy with reduced latency in forwarding the data to the sink. Minimization of energy and latency can be achieved by having efficient algorithm for the selection of membership nodes as well as efficient route determination. For this we proposed the local update routing which has two different phases. They are neighborhood discovery with route setup and route maintenance.

3.1. *Local Update Routing*

Network deployment is made level by level. Each FFD is employed with a counter. After deployment the FFDs starts the counter. The first phase is the neighborhood discovery phase which is shown in fig.3. After deployment all the FFDs broadcast their presence with their id and count value. The RFDs checks the messages received. Among that it will select the PAN coordinator based on the less count value and reply to that FFD with its id. FFDs check whether six or more messages are received. If more than six messages received then among that it will select one from upper FFD and five from RFDs. If it doesn't receive any messages from upper FFDs then it will select one FFD from the same level and five from RFDs. At the same time if it received more than five messages from RFDs then it will select any five and consider that as children. All other RFDs will be discarded. For the unselected nodes the current FFD will sent the non-selection message with FFD's id.

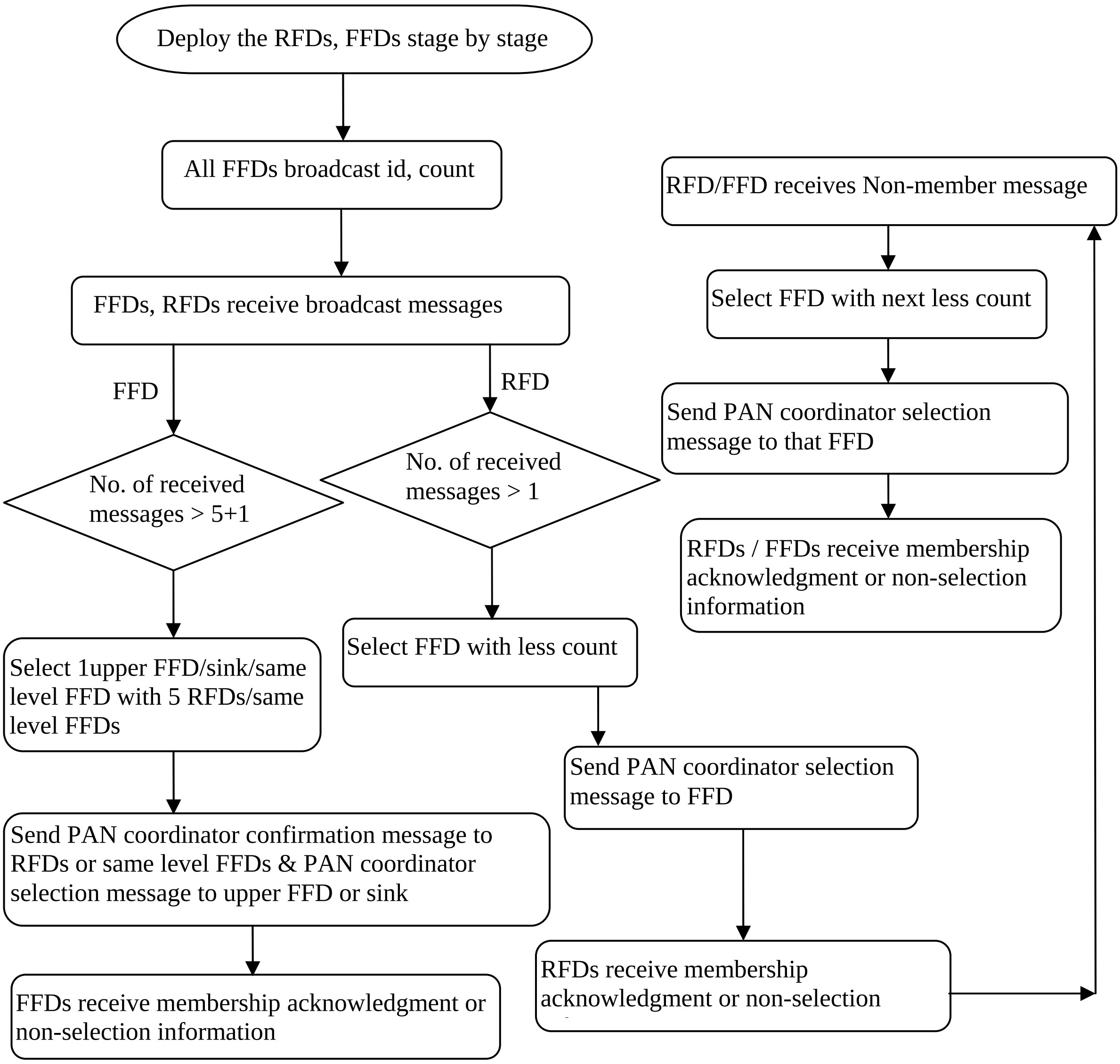

Fig.3. Flowchart for membership selection

Upon receiving the non-selection message the RFD again sent its id to other FFD. The process will be repeated till RFD gets a PAN coordinator FFD. When members are selected by the PAN coordinator the route is setup to sink node. If any node fails then the prior information is locally updated to the corresponding PAN coordinator and its members before the node failure. Then the new route is established based on the above procedure. The flow chart for the initial process is shown in fig.3.

There are four different messages used in the initial process. They are broadcast message, PAN coordinator selection message, non-membership message, and acknowledgement message. The broadcast message is the initial hello message sent from all FFDs. It contains the fields as,

From FFD==> id(FFD) , count value.

The PAN coordinator selection message is the selection message sent by RFDs or FFDs to the selected PAN coordinator. It contains the fields as,

From RFD==>id(RFD), id(FFD)-PAN coordinator.

From FFD==>id(FFD)-sender, id(FFD)-PAN coordinator .

The non-membership message is sent by the PAN coordinator. It couldn’t select all as member due to the unavailability of resources. The message contains the fields as,

From FFD==>non-member, id(RFD/FFD), id(FFD)-PAN coordinator.

The acknowledgement message is the selection of membership nodes sent by the PAN coordinator to its members. The message contains the fields as,

From FFD==>Member, id(RFD/FFD), id(FFD)-PAN coordinator.

At the end of neighborhood discovery phase, all the nodes are connected with a PAN coordinator like the hierarchical structure shown in fig.6. Thus in the route setup phase the data sensed by the RFDs will be forwarded to the PAN coordinator which in turn forward to the next tier PAN coordinator. Finally, the last tier PAN coordinator forward the data to the sink node.

The second phase is the route maintenance phase. Here the maintenance process comes to picture, i.e.; how to forward the data to the sink node whenever any link or node fails. In order to overcome the situation new route has to be established or the old route has to be repaired. These actions have to be taken before the failure occurs in order to maintain effective communication. This maintenance process can be undergone with the following steps.

Step-1:

Every PAN coordinator continuously monitors its energy level and if it is below the threshold level then sends the energy information to its members.

Step-2:

Based on the received energy information the member nodes either go for the new selection of the PAN coordinator or stay some more time with the same PAN coordinator using the same failing link.

Since the member nodes update their PAN coordinator locally and thus we named it as a local update routing.

3.2. *Hierarchical WPAN*

In the wireless underwater sensor networks hundreds of sensor nodes are used in different depth level of sea. So multiple WPAN structure can be developed in order to monitor and control the network efficiently. WPAN can be designed in a hierarchical manner with only one difference in the basic structure, i.e; in the low tier WPAN, which is deployed in the deepest level of sea, all the membership nodes will be RFDs and in the remaining tier WPANs, all the membership nodes will be FFDs. Basic and hierarchical WPAN structures are shown in fig. 4 and fig.5.

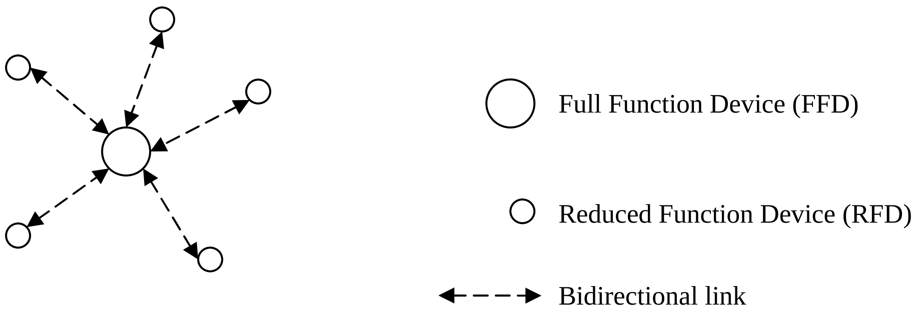

Fig.4 Underwater WPAN structure

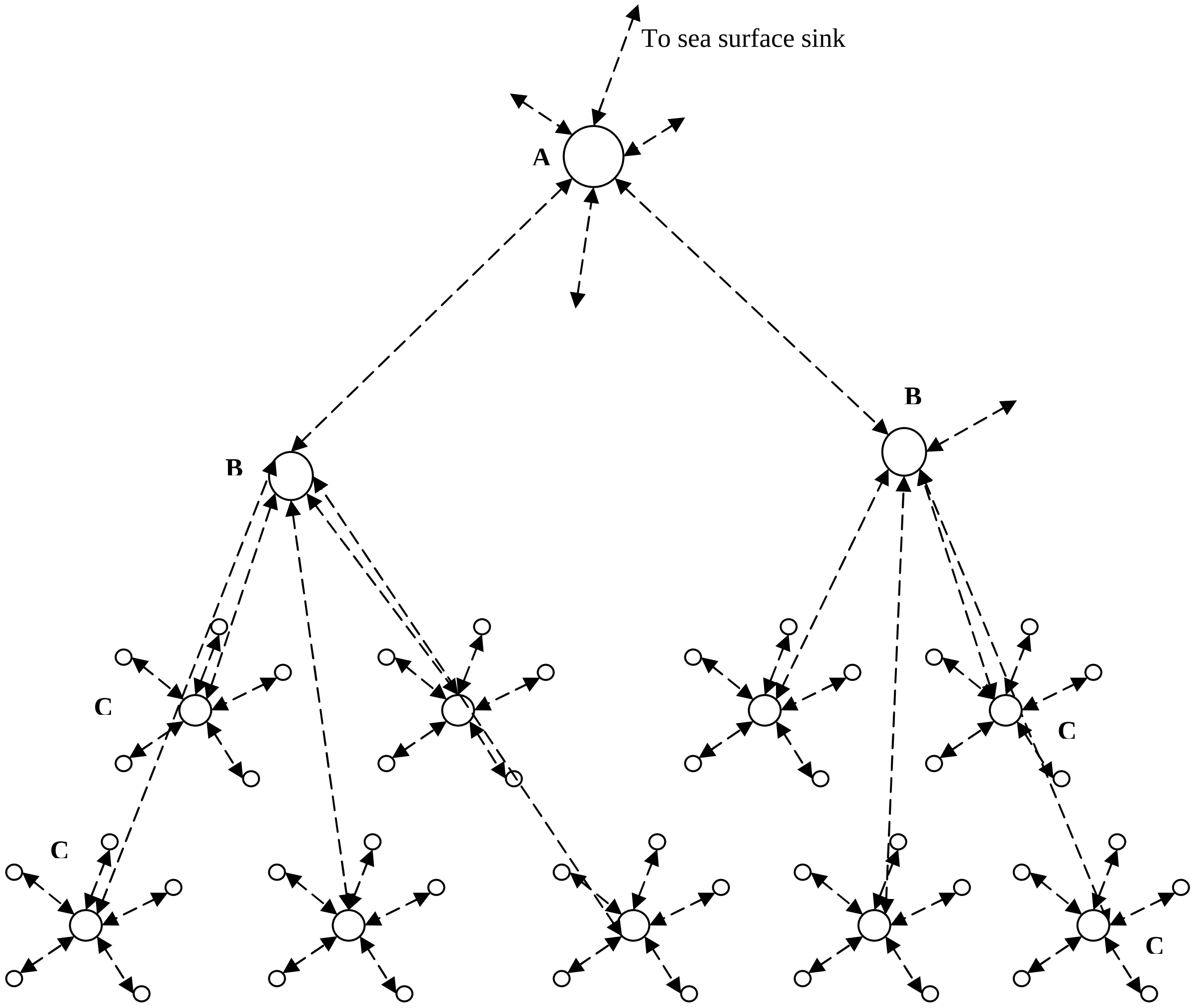

Fig.5 Underwater Hierarchical WPAN structure

3.3. *Network Setup*

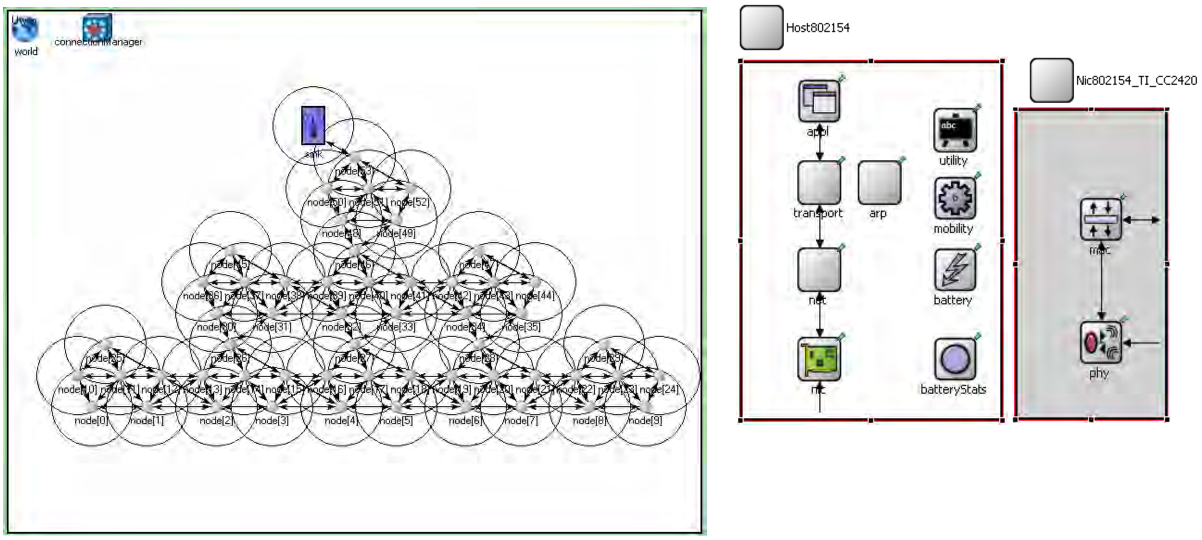

Fig.6 UWSN- network setup

The UWSN setup is shown in fig.6 with the sub modules of the sensor nodes. Using Omnet++ simulator and MiXiM framework the network is created. Here the network consists of 54 sensor nodes and only one sink node.

Among that 29 nodes are FFDs and the remaining 25 nodes are RFDs. Initial parameters set in the various layers and in the sub modules are shown below in the Table1. The conditions considered for our wireless underwater sensor network is to have homogenous nodes. All sensor nodes are designed with mobile unit but they are considered to be immobile throughout the simulation.

Table 1.Parameters set for the UWSN

connectionManager.carrierFrequency = 868e6Hz /915e6Hz /2.4e9Hz	battery.resolution = 10s battery.publishDelta = 0.1
connectionManager.pMax = 1.1mW	battery.publishTime = 0
connectionManager.sat = -83dBm	battery.numDevices = 6
connectionManager.alpha = 2.5	applType = "SensorApplLayer"
phy.usePropagationDelay = true	appl.trafficType = "exponential"
phy.useThermalNoise = true	appl.broadcastPackets = true
phy.maxTXPower = 1.1mW	appl.nbPackets = 3
phy.sensitivity = -100dBm	net.stats = true
battery.capacity = 99999mAh	net.headerLength = 24 bit
battery.voltage = 3.3V	

4. Simulation Results

Simulation is performed under three different carrier frequencies using Omnet++ simulator. They are 915e6Hz (LF1), 868e6Hz (LF2) and 2.4e9Hz (HF). The outputs obtained after simulation under three different scenarios LF1, LF2 and HF are shown in fig.7 to fig.14.

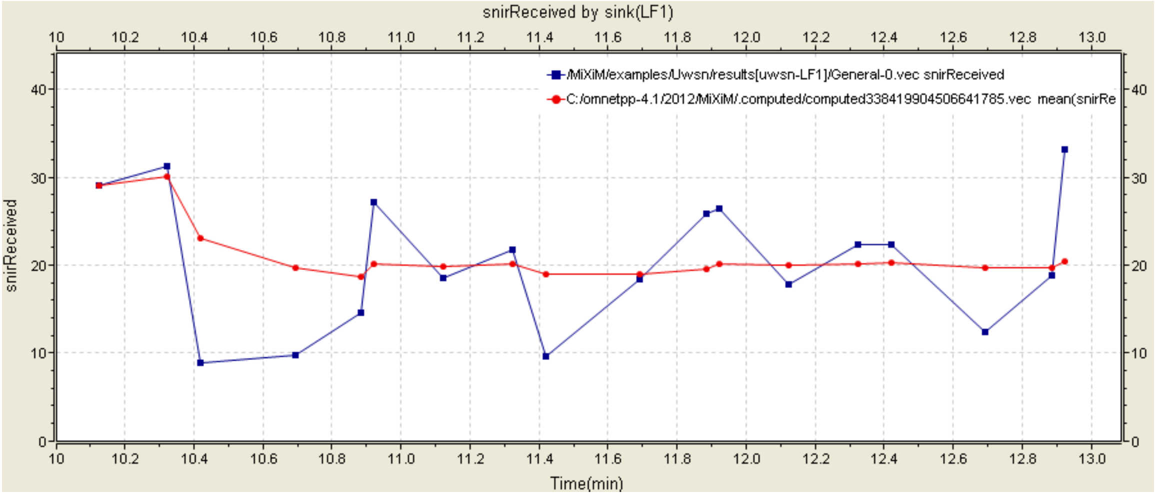

Fig.7 SNIR-Received by sink with 915e6Hz

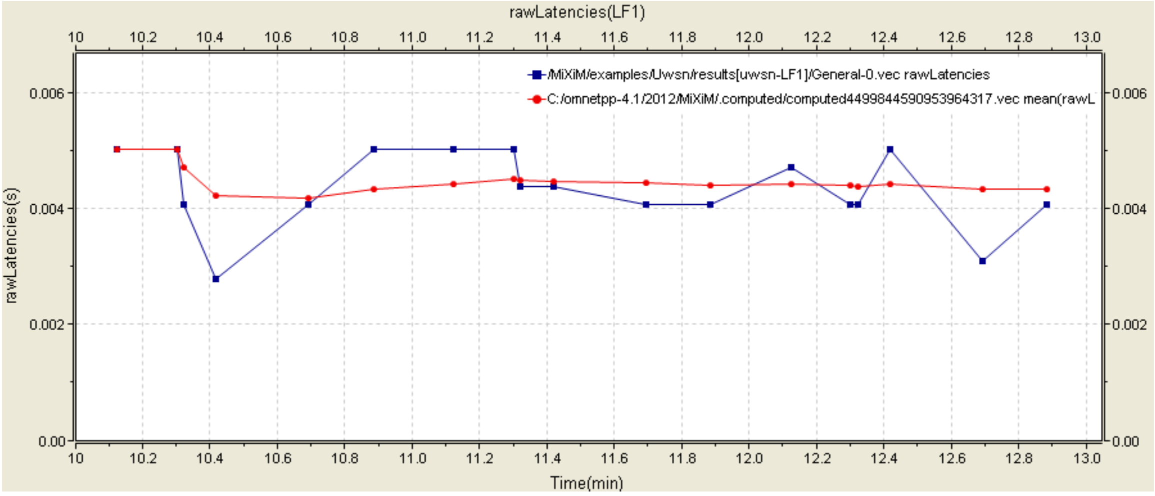

Fig.8 Latency with 915e6Hz

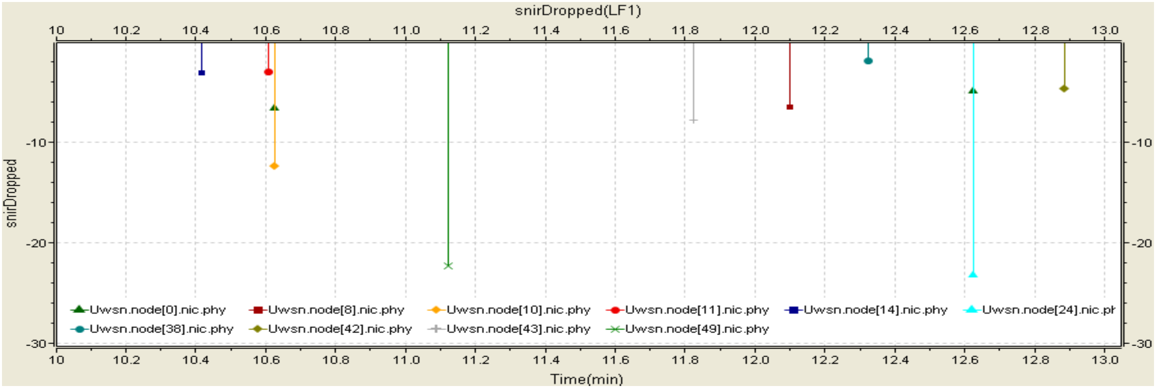

Fig.9 SNIR-Dropped with 915e6Hz

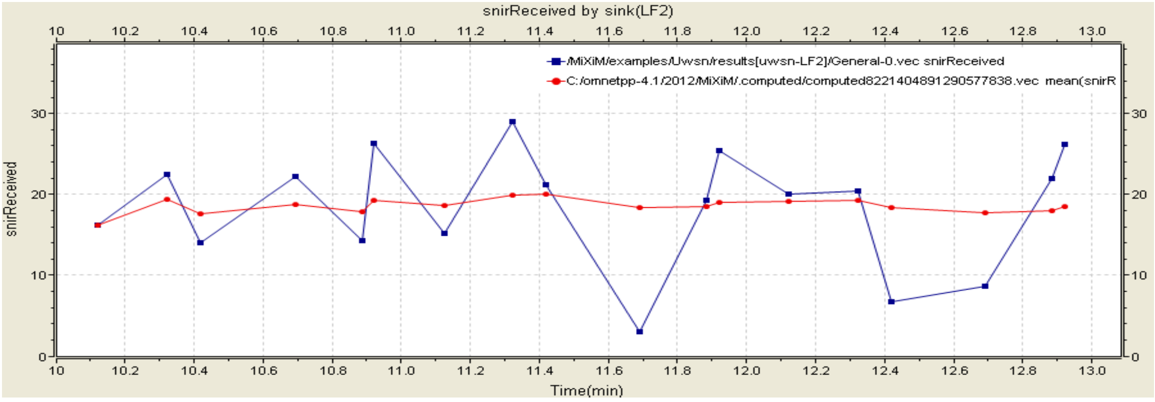

Fig.10 SNIR-Received by sink with 868e6Hz

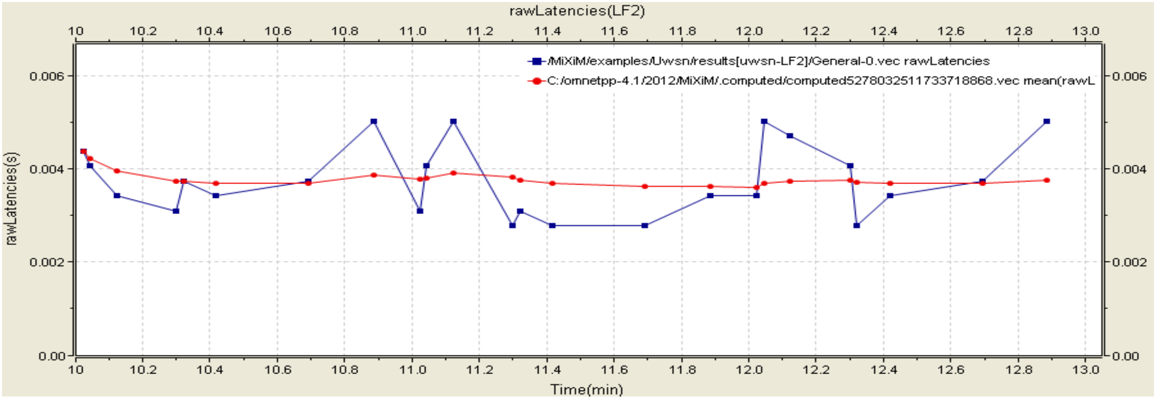

Fig.11 Latency with 868e6Hz

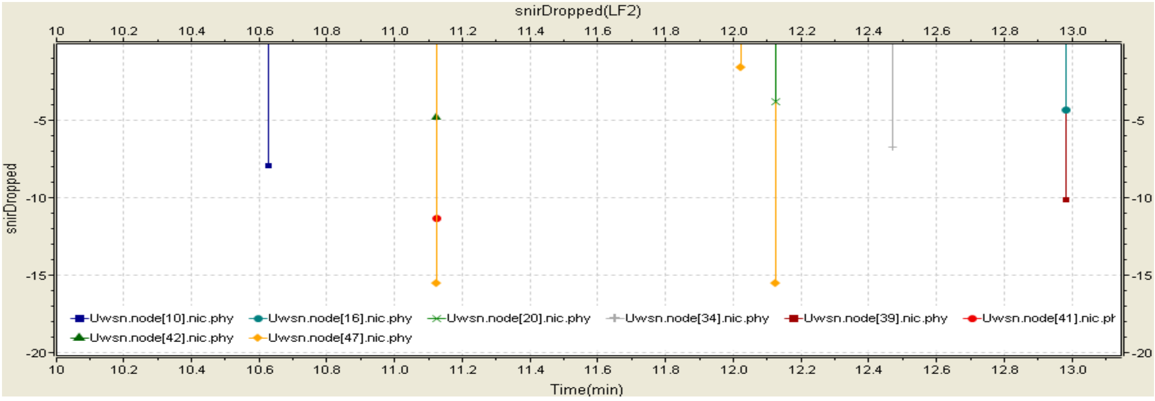

Fig.12 SNIR-Dropped with 868e6Hz

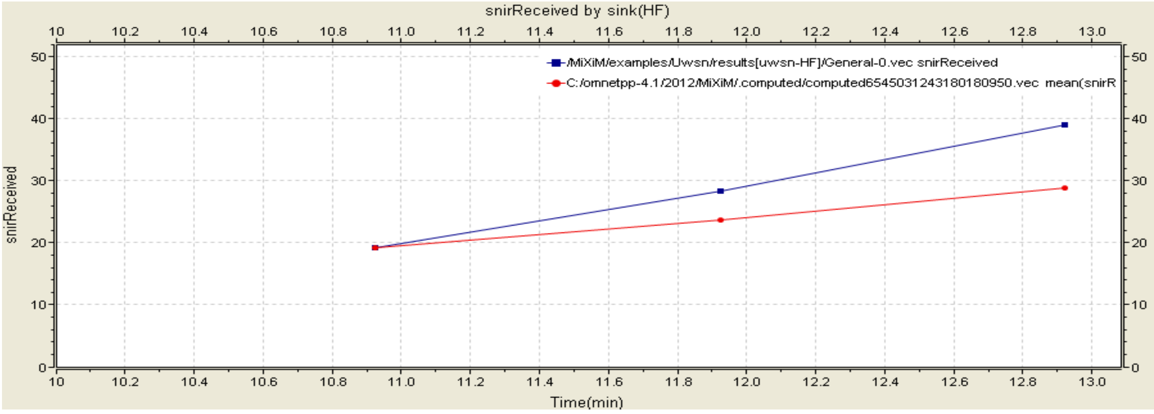

Fig.13 SNIR-Received by sink with 2.4e9Hz

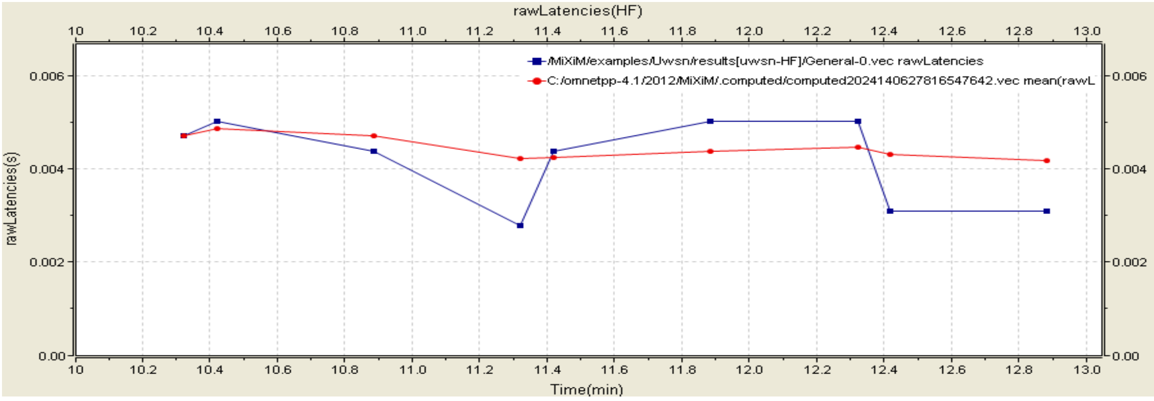

Fig.14 Latency with 2.4e9Hz

All the scenarios are simulated for 15 minutes and also the network throughput and latencies in the network are monitored and measured. From the output graphs it is seen that latency is minimized and also dropped SNIR is reduced with lower carrier frequencies.

5. Conclusion

From our simulation result it is seen that with the lower carrier frequencies the network throughput is increased and also the latencies in the network are reduced. The propagation delay is reduced or the mean end to end delay is reduced which in turn save the transmitting/receiving power through which network lifetime is improved by the selection of proper route using local update routing algorithm with hierarchical WPANs.

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