Performance Analysis of Round Trip Delay Time in Practical Wireless Network for Telemanagement

El Miloud Ar Reyouchi, Kamal Ghoumid, Koutaiba Ameziane, Otman El Mrabet, Slimane Mekaoui

Abstract**—**In this paper we focus on the Round Trip Delay (RTD) time measurement technique which is an easy way to obtain the operating condition information in wireless network (WN). RTD measurement is affected by various parameters of wireless network. We illustrate how these RTD parameters vary (in a telemanagement application) versus distance, baud rates, number of hops, between nodes, using radio modem & router unit as a means of transmission and wireless routing.

Keywords**—**Wireless Network, Round Trip Delay, Radio modem, Router.

I. INTRODUCTION

THE rapid development of signal processing techniques recently attains a high performance industrial narrow band communication systems which had been for long years dominated by the traditional analog circuit design. Although it brings new potential to even increase the efficiency of the radio channel usage it also forces new challenges and compromises that radio designers have to face.

The industrial narrow band communication systems specified mostly by the European standard EN 300 113 [1] are used in challenging environmental and radio conditions. Such systems call for a dynamic range in the vicinity of 100 dB, strict adjacent channel transmitted power requirements, high data sensitivity, adjacent channel selectivity, radio blocking or desensitization, co-channel rejection and others [1], [2]. The radio transceiver has to be small in dimensions, consuming low power and remains all the parameters over wide industrial temperature range and over the extensive period of time for reasonable price and at the same time provides enough flexibility to accommodate different channel bandwidths, various digital modulations formats and data rates. The Radio Router can be set up to allow each site to operate as individual Drop repeaters with the ability to_call specific repeater sites as well as an ALL CALL function. Each site with its specific NAC code will operate as a local repeater only. When the drop repeater receives a NAC code for a specific site it will key up that site only. Radio modem & router is best suited for transmission of a large number of short messages where a guaranteed delivery time is required, i.e. for mission critical applications.

The standard radio modems (UHF or VHF) offer different rate baud digital communication channel. Factors influencing radio performance are: antenna height and type, the sensitivity of the radio, the output power of the radio and the complete system design. Radio modem & router wireless can increase the transmission performance of a complex network of processes and monitoring radio. Transmissions and receptions are achieved by means of an antenna and can be “directional” (Point-to-point focused beams employing high frequencies) or “Omni-directional” (Waves propagating in all directions using signals of lower frequencies).

Wireless Network communications is a rapidly growing segment of the communications industry, with the potential to provide high-speed high-quality information exchange between portable devices located anywhere in the world [3]. RTD time is the time required for a packet to travel from the source (SCADA center) to the destination (remote RTU) and back again. RTD time is an important metric in determining the behavior of a connection. RTD is useful in measuring the congestion window size and retransmission timeout of a connection, as well as the available bandwidth on a path [4]. This information can help determine factors that limit data flow rates and cause congestion [5]. When known at a network link along the path, RTT can also aid efficient queue management and buffer provisioning. Additionally, RTD can be used to improve node distribution in peer-to-peer and overlay networks [6].

The purpose is to sense, collect and preprocess the information from all Radio modem & Router nodes in network. In such wireless network having some important sites of broadcast TV/FM identification of node, locating the distance of target node with respect to reference node [7] and detection of failed node becomes most difficult elements to study, [8]. Failure detection of node in WN is essential because failed or malfunctioning node may produce incorrect data or no data, which will affect the overall quality of the entire WN. Manually checking of such failed sensor node in WN is troublesome and impossible.

Round Trip Time is dependent on a number of factors, including the data transfer rate of the source, the nature of the transmission medium, the distance between the source and the destination, the number of nodes between the source and the destination, the amount of traffic or bandwidth on the network that is being used, the number of other requests being handled by the receiver or nodes along the transmission path, the

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processing capabilities of the source, receiver, and nodes, and the presence of interference.

So it is necessary to study the relationship between the round trip delay time and router node distance, baud rates and number of hops. To prove this relationship the other parameters affecting round trip delay time like speed, data transfer rate, number of router nodes in RTD time path and other request handled by intermediate nodes are either made constant or disabled. The graph plotted between round trip delay time and radio router node distance baud rates, number of hops, prove a linear relationship between them [9], [10]. In this paper we focus on Round Trip Delay Time (RTD) because it is both simple to measure and interpret, and widely used in the design of performance sensitive applications such as network any cast, [11], [12] or media content delivery [13], [14]. This paper is arranged into six sections including introduction. Section II gives a main of objectives of our experiment. Section III gives overview of round trip delay, factors affecting it. Section IV describes the experimental setup used to prove this relationship. In Section V real time hardware simulation results are presented. Conclusion and future works are presented in Section VI.

II. Objectives

The centers of broadcasting TV/FM in rural mountainous are often located in sites of high altitude and the access is very difficult and sometimes inaccessible (during the bad weather) which has a high error rate. In the case of a failure we do not know at what level to find the failure, in order to prepare the mission, in addition, these centers are isolated; their operation is not monitored nor operated or has remote control. Therefore, this allows the better functioning of the communication with local fixed networks (which are the centers of broadcasting TV / FM) and one or two mobile devices (which are the regional maintenance teams) using Rip EX Radio modem & Router as the transmission medium with Simple Network Management Protocol (SNMP) and line of Line of sight (Lo S) as of propagation mode. The main objective is to see how RTD (between source and destination) varies depending on the distance, baud rates, number of hops and packet Length in a practical and particular WN (shown in Fig. 1). In order to operate in lower population density areas, using channels in the VHF and UHF bands and with a coverage of the rural area around a village, shown in Fig. 1, we created to control the equipment TV / FM broadcast centers: a transmitter TV / FM, many satellite receiver multiplexers, inverters, energy parameters and so on (see Fig. 2).

The round trip delay and confidence factor is the most powerful tools among them [15]. The minimum imposed condition for RTD time measurement is that at least 3 router nodes should be present in a loop in a communication full-duplex system. This RTD time measurement is affected by various parameters. In WN having 'N' router nodes if any one router node fails or starts producing improper data (malfunctioning) the time delays related to this router node will change. This will introduce errors into the RTD time estimates. A brief analysis of RTD time errors can be found in [16].

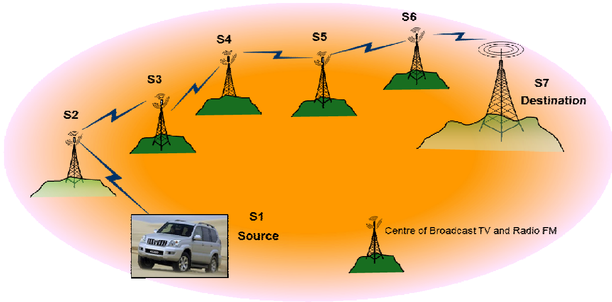

Fig. 1 Wireless Network consisting seven nodes with maximum 1 path (round-trip) for RTD measurement

Fig. 2 The equipment's TV and radio FM broadcast centers (S7)

III. Round Trip Delay

A. Round-Trip Delay (RTD) Time

Round-trip delay (RTD), also known as round-trip time (RTT), is the time required for a signal pulse or packet to travel from a specific source node (transmitter) thru path consisting in another node (receiver) and back again. The round trip delay time can range from a few milliseconds (thousands of a second) under ideal conditions between nearby spaced router nodes to several seconds under adverse conditions between router nodes separated by a large distance [7]. RTD is always related to telecommunication, but may refer to the Internet, satellite Radio router communications, and radar systems. Round Trip Time can refer to a wide variety of transmissions, such as copper-cable Internet transmissions, wireless Internet transmissions, satellite transmissions, and cell phone transmissions. In Internet transmissions, the RTD may refer to "ping time", which is the amount of time data can be sent to a remote location and sent back, and may be identified by using the ping command. In satellite transmissions, the RTD can be calculated by using the Jacobson/ Karels algorithm. Let us consider the wireless network having seven nodes as shown in Fig. 1. Considering the condition of having seven nodes in RTD path, it comes that in this Wireless Network the maximum RTD path (worse case) present will be given by (1), a same round-trip path. These are as follows:

RTD-RTT (S1-S2-S3-S4-S5-S7-S6-S5-S4-S3-S2-S1)

RTD, expressed in milliseconds, is the elapsed time for a request to go from node 'S1' to node 'S7,' and for the reply from 'S7' to return to 'S1.' The RTD is the total time for the round-trip. The forward and reverse path times do not need to be the same, but in our real application is the same. RTT depends on the network infrastructure in place, the distance between nodes, network conditions, and packet size. Packet size, congestion, and payload compressibility have a significant impact on RTD for slower links. Other factors can affect RTD, including forward error correction and data compression, which introduce buffers and queues that increase RTD. The RTD time for RTD path in above network (our case a particular signal crosses same path round-trip) is calculated by using the following equation:

$$T_{RTD} = \tau(1,2) + \tau(2,3) + \tau(3,4) + \tau(4,5) + \tau(5,6) + \tau(6,7) + \tau(7,6) + \tau(6,5) + \tau(5,4) + \tau(4,3) + \tau(3,2) + \tau(2,1) \quad (1)$$

where $\tau(i,j)$ is the delay time between the node i and j respectively. With the help of this equation-1, the generalized equation for RTD time for the RTD path containing N nodes will be written as follows

$$TRTD = \tau(1,2) + \tau(2,3) + \text{------ --------} + \tau((N-1),N) + \tau(N,(N-1) + \text{-------} + \text{-------} + \tau(3,2) + \tau(2,1) \quad (2)$$

In the case where the signal crosses different paths, [9], the equation will be:

$$TRTD = \tau(1,2) + \tau(2,3) + \text{------ --------} + \tau((N-1),1) \quad (3)$$

The τ (1,2) time delay between the node 1& 2 depends upon the distance between them. Time delay is directly proportional to distance and expressed as:

$$\tau(1,2) \propto d(1,2) \quad (4)$$

RTD time expressed in (1) depends upon the various time delays in the selected path. All these time delays are linear function of distances. Hence RTD time should be a linear function of distance, baud rates, and number of hops between nodes. Here in this paper it has been proved experimentally.

B. Factors Affecting RTD Time Measurement

In a wireless network RTD time is affected by several factors. One of them is latency, which is the time between a request for data and the complete return or display of that data. The round trip delay (RTD) time depends on various factors including:

a) Data transfer rate of the node
b) Nature of the transmission medium
c) Physical distance between the nodes
d) Number of nodes in the RTD path
e) Number of other requests being handled by intermediate nodes
f) Speed with which intermediate nodes and source node functions
g) Modulation mode
h) Presence of interference in the circuit.

As stated above the round trip delay time is a function of various parameters of the wireless network and can be expressed by following equation:

RTD Time = ***f*** (speed, distance, modulation, medium, noise, nodes in RTD path & request handled)

$$= Ts + Td + Tmod + Tm + Tn + TnRTD + Toreq \quad (5)$$

A theoretical minimum is imposed on the RTD (minimum 3 in different back paths) because it can never be less than this value. Then it will not form a loop in transmission medium. As the RTD measurement depends upon various parameters [15], [8] of Radio Router Node and Wireless network. The Wireless Network for various paths round trip delay (RTD) measurements has to be categorized as Symmetrical or Asymmetrical network. A Wireless network is briefly defined as Symmetrical network if:

1) All the nodes are located at equal distance from each other.
2) All nodes should have same sensitivity.
3) Operating speed of all nodes (Routers) processing unit has to be equal.
4) Same wireless communication module is for all nodes (Routers). Otherwise the Radio Router Wireless Network will be defined as Asymmetrical network (in our application).

IV. Experimental Setup

A. Hardware Selection and Configuration

The equipment's, including computer software used, are:

- Eagle Eye V1.1 monitoring Software adapts to particular needs by providing tools for the supervision and control of the installations of the equipment's of broadcasting. This software can covertly send the logs to your email address. Ensure you know everything that occurs on your computer even when you're miles away with Eagle Eye. It can collect, at the S7, site all information about the sites between the source and destination.
- Seven Rip EX units (Radio modem & routers) which are characterized by the SNMP management that will support the base MIB (Management Information Base) SNMP (Simple Network Management Protocol) Protocol through the MIB browser.
- The Rip EX units use the same band VHF /UHF (band IV and V); VHF/UHF bands 350 MHz this band is somewhere between 160 and 450 MHz reserved to broadcasters which have highly favorable propagation characteristics. Penetrating through foliage and structures, they reach far and wide distance more than WIMAX, [17].
- We can use the omnidirectional antenna KA160.3 which is designed for base radio stations working in bands of

158-174 MHz. The antenna has an Omni-directional radiation pattern with the gain of 3 dB and is suitable for the top-mounting. The antenna is broadband and that is why it is suitable for duplex operations. Also we can use the same antenna system, for transmission, that is already used by the broadcast Digital Terrestrial Television (DTT) UHF system or radio FM VHF.

- The values received at the level of each site vary between 38 and 70 dB µV which is recommended to plug user for correct operation of household appliances for the bands III, IV and V.
- The output power of each router varies between 0.1 and 10 watts (default=10watts) and this in order to achieve the long distance which separates the TV/FM broadcast site and that is the purpose of selection techniques and interconnection equipment to build a logical architecture for local area network (sites at each TV / FM).

We will select sites in our application area (northern Morocco) in such a way or path that the distances between these sites successively are equal (Fig. 3). To the left of Fig. 3 is the measurement of broadcast equipment TV and FM radio which has been selected in the right wireless network where will practice RTD measurements.

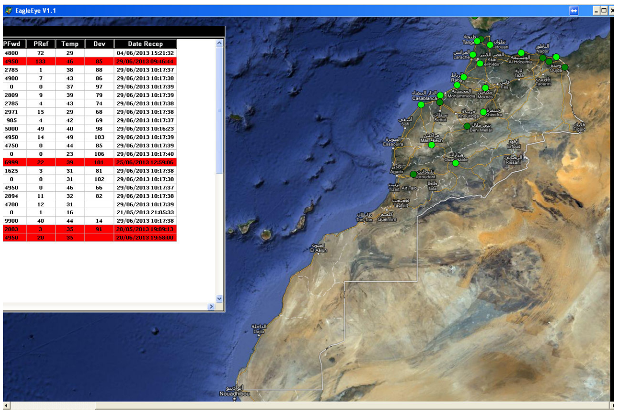

Fig. 3 Real interface Control equipment (with Eagle Eye V1.1) which exists in the main center of broadcast TV/FM (center "Palomas" number S7 see Figs. 1 and 5)

We are in the condition where a signal travels over the air directly from a wireless transmitter to a wireless receiver without passing an obstruction Line-of-sight (LOS), because in LOS environment, signal can reach longer distance with better signal strength and higher throughput.

The obtaining of the round-trip delay time (RTD), or round-trip time (RTT), using the Dock light V2 or «Ping» (acronym of Packet Internet Groper) followed by the IP address of the destination S7 (See Fig. 5).

To measure the RTD, packets are sent from the source to the destination using the ping utility, over different route lengths. In the case where no fault is detected on Wireless network Rip EX units, the correct data centers measurements are obtained (see inverted variables make Eaton) measurements in Fig. 4.

Failure detection of radio modem & router node in WN, thanks to RTD, is essential because failed or malfunctioning Rip EX units node may produce incorrect data or no data, which will affect the overall quality of the entire WN. Manually checking of such failed Radio Router node in WN is troublesome and impossible.

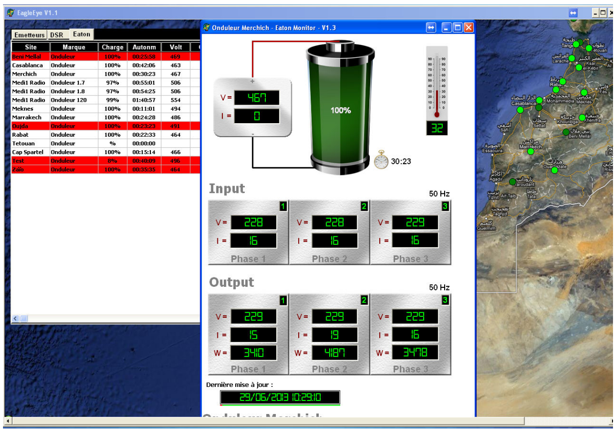

Fig. 4 Example of (inverted variables make Eaton) measurements of equipment device (Power ware 9355-20KVA UPS) after verification of WN by means of RTD

B. Selection of Various Network Conditions

As the RTD measurement is affected by various parameters of the wireless network mentioned in (5). The various conditions have to be imposed on the selection of network before applying this method. So except distance, baud rates, and number of hops other parameters affecting RTD measurement are kept constant. These conditions are mentioned in Table I given below.

TABLE I
CONDITION IMPOSED ON SELECTED NETWORK

Sr. No.	Factors Affecting RTD measurement	Condition Imposed or Chosen
1	Modulation rate [kbps] Payload modulation	83.33| 16DEQAM-
3	FEC (Forward Error Correction)	Off
4	ACK	ON
5	Interface speed	ETH TCP/IP (see 5.2)
6	The nature of the transmission medium.	Wireless
7	The physical distance between the Rip EX units(radio modem & router) nodes	Variable with Symmetrical network
8	The number of Rip EX units (radio modem & router) nodes in the RTD path	(m=07) the same path round trip
9	The number of other requests being handled by intermediate nodes	NIL
10	The speed with which intermediate nodes and source node functions	Same due identical hardware (in sec)
11	Proceeding Time	20ms on all RipEX units
12	The presence of interference in the circuit	Insignificant

Data transfer rate and speed of communication of nodes are same as Rip EX units wireless communication module. If more nodes are used in RTD path it will increase the RTD time [8]. This will not affect the linear relationship between the RTD time and Rip EX units node distance, baud rates and number of hops.

V. Simulation Results

Initially the each Rip EX units node in Wireless Network as shown in Fig. 5 is defined for a selected round trip delay path by configuring them with source and destination addresses by using the protocol SCADA software. RTD path selected here is RTD (S1-S2-S3-S4-S5-S7-S6-S5-S4-S3-S2-S1) and the RTD path distance is 5 Km.

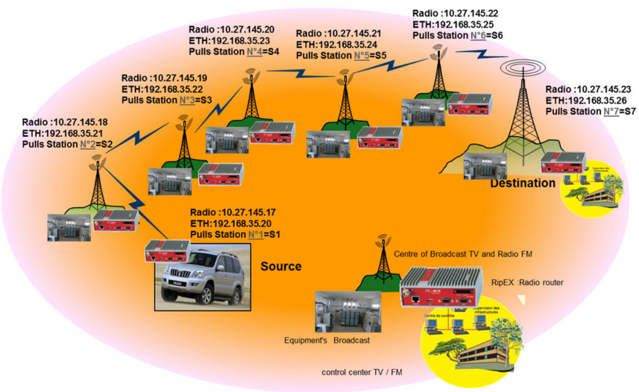

Fig. 5 Network Topologies being studied

One possible scenario is considered: (Fig. 5) direct transmission between the source (N^{O} 1=S1) and the Destination (N^{O} 7=S7) using seven Rip EX units (radio modem &Router)

S1 has source address of master; each Radio router in the path (S1-S2-S3-S4-S5-S7-S6-S5-S4-S3-S2-S1) has source address and destination address (Fig. 5). After configuring these slaves Rip EX units nodes in WN it is simulated in real time by using the Dock light V2 software or ping command followed by the address of the destined Rip EX units (Node S7). The above procedure is repeated for remaining five causes. For these cases radio router nodes are kept at distances 10 km, 15km, 20km, 25km, 30km, respectively.

A. RTD Measurement at Different Distances

Here we have to prove the relationship between the RTD time and Rip EX units Node Distance. So the distance between the Rip EX units nodes is kept variable under symmetrical network conditions. Round trip delay path is kept fix. Rip EX units nodes are kept at various distances as 5, 10,15,20,25 and 30 Kilometers respectively and then real time results are taken.

The RTD time values measured for six different cases are 566.86, 568.01, 570.01, 571.76, 573.21 and 574.86 m.sec respectively. Results of simulation are showed in Fig. 6.

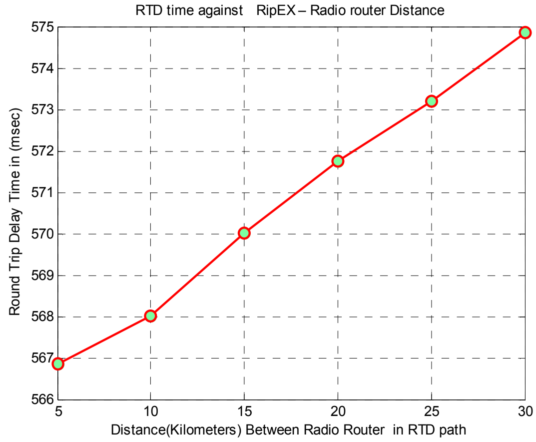

Fig. 6 RTD time against Radio Router Node Distance

From the readings it is observed that as distances change in 'Kilometers' the RTD time changes in 'ms'. As the distance between Radio Router nodes in WN changes, it will change the time delay between the consecutive radio router nodes, which in final run affects the RTD time measurement [7].

The change in RTD time against distance between radio router nodes is verified by considering six cases. The round trip delay time (ms) against radio router node distance (kilometers) in graph is shown in Fig. 6. It gives us the linear relationship between the distance and round trip delay (RTD) time of radio router nodes [7].

It is observed from the above results that as the distance between the radio router nodes in round trip delay path increases the round trip delay (RTD) time also increases. In above experimental case the parameters affecting RTD measurement except distance are kept identical. So the round trip delay (RTD) measurement in these cases is purely a function of distance between the radio router nodes. Hence linear relationship exists between round trip delay time and radio router node distance in WN.

The graph plotted between round trip delay time and router node distance proves a linear relationship between them.

B. RTD Measurement at Different Baud Rates

The aim of this experiment is to measure the RTD of the Rip EX units as a function of the baud rates and the packet length to gain a sense as how does the baud rate affect the latency of the modules communicating over SCADA protocol. For this experiment, the topology shown in Fig. 5 is considered. Rip EX units module configured as a source S1 sends packets to destination S7 and come back to S1 and calculates the total transmission time. Several measurements are carried out, in comparison to different values of packet length and baud rates, each Rip EX units module may support up to 1500 bytes (User data size without any headers (IP, TCP, UDP, …) of RF payload. Therefore, to avoid reception overcharge with the SCADA communication protocol, we used a lower value of packet length up to 140 bytes. The RTD in this case is shown as a function of packet size and the baud rate as illustrated in Fig. 7.

This experimental trial is repeated ten times. In addition to, this experiment was conducted to have a performance baseline for WN networks using Rip EX units modules. It was observed that the network RTD decreases as the baud rate increases.

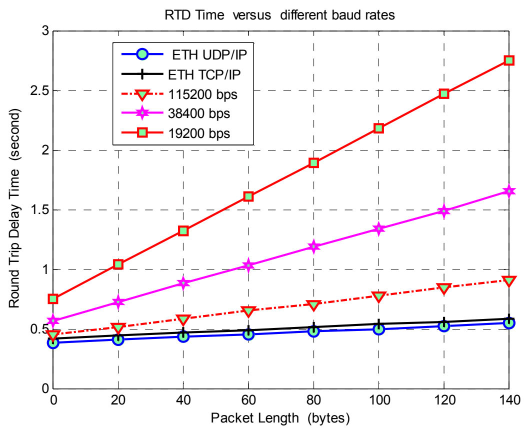

Fig. 7 RTD versus packet size depending of different baud rates

C. Packet Delay

Another significant indicator of Rip EX units Wireless Network performance is the packet delay between two consecutive packets accurately received by the source S1. The packets delay for this experiment is defined as the duration between sending a packet and until the entire packet has been received by the source also known as round-trip time (RTT). The distance between Radio modem &Router Nodes is 5km and packet Length is fixed for 125bytes. Fig. 8 shows the results of direct transmission from a source to Destination and indirect transmission through Radio Routers. For tree hops transmission, the average delay is around 0.19 sec for the maximum payload offered, while 0.28 sec for four hops, 0, 35 sec for five hops, 0.48sec for six hops and 0.57 sec for seven hops respectively. Fig. 8 also shows more details of how RTD varies in terms of different packets length (0 up to 140 bytes) of different hops.

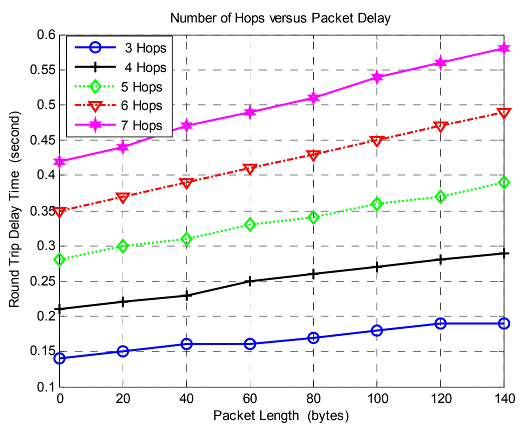

Fig. 8 RTD versus Packet length for different hops (without FEC)

The results in Fig. 8 show that the presence of the Routers has a significant effect on the data rate and the RTD of the entire network.

Hence, the packet delay increases significantly with the number of hops due to an extra processing delay at the Routers and retransmission delay due to additional hop.

VI. Conclusions and Future Works

In this paper, we have analyzed the performance of particular and practical network topology of Rip EX units wireless communication module based wireless network. We considered a scenario with direct wireless transmission round-trip from the source S1 to the destination S7 and with the presence of (Rip EX units) Radio modem & Routers for relaying messages. For multi-hop transmission with Rip EX units our results show that:

- As the distance, between the radio router nodes in round trip delay path, increases the round trip delay (RTD) time also increases.
- It was observed that the network RTD time decreases as the baud rate increases.
- The packet delay increases significantly with the number of hops, in the route, due to an extra processing delay at the Radio Routers and retransmission delay due to additional hop. It was also observed that the RTD varies with the packet size.

Therefore, to improve the system performance, the number of transmitting nodes should be minimized or find new techniques and methods to improve the factors affecting RTD time measurement which will be our future works.

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