Power Quality Command And Control Systems In Wireless Renewable Energy Networks

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***Abstract*— Command and control in real time of renewable energy are a fast-growing trend. The development of communication platform uses energy management software (Power studio technology) as a basis design for an overall system. The proposed prototype constructs Power Quality Analyzer. The main central control system will acquire data from the remote renewable energy system. All necessary monitor data include Voltage events and variations, Flicker, Harmonics, Unbalance and other control parameters will be stored in a control unit. Monitoring data is monitored as real-time data across Wireless Communication Systems using router in bridge mode to connect multiple devices wirelessly at the Power Quality Analyzer. This paper presents the metric application of Power Quality command and control systems for smart renewable energy power of useful Information. The authors approve that the metric application, Payload bitrate/forwarding time vs average message size, offers a remarkable flexibility results and gives a quick and easy idea of the possible Bitrate/Time in the wireless bridge network performance.**

Keywords- Renewable Energy;Energy Management System ; Power Quality Analyzer; Command And Control Systems;Wireless Communication Networks.

I. INTRODUCTION

Renewable energy is one of the factors generating not only a descendant but also a not bi-directional flow, with all the consequences that come up on the grid: Risk Surge, new management "pockets" of energy, etc. . . . The challenge that poses is to integrate them at any point of the network, while managing different demands. The identified renewable energy resources include wind, small hydro, solar, geothermal, and waste [1].

In the framework of project supervision and the modern control wind of energy production systems, SCADA software [2], [3] has been chosen for its reliability, scalability and performance in client-server architectures. The remote management and intelligence have envisioned offering a diversity of advantages over the real-time system in terms of digitalization, intelligence, sustainability, flexibility and customization [4], which entitles the name Smart Grid to the next generation power systems. This solution significantly reduced maintenance costs while it centralized all information received remotely and facilitated its control. The main objective was to provide remote access to information produced by the fields of renewable energy (solar, wind...), including alarms and histories data. The control system installed at each site samples the main operational data from the generators and the various positions. These systems are connected to the CORE (Operating Renewable Energy Centre) via long-distance communication links.

The CORE uses these data to identify view, diagnose eventual problems, and bring them a solution. Initially, each node was controlled from a local SCADA station and the operators had to send the data by phone. All the required data where been saved on disk and then transmitted to the person responsible for the recorded data. To ensure the remote-control nodes and remote control by means of a dedicated network, thus, we have decided to install architecture SCADA within the equipped CORE.

The integrated SCADA system CORE provides operators with all the information they need about alarms from the reactions made by a renewable energy. Client stations, which communicate with the front end over a TCP / IP Ethernet network redundant to 1000 Mbps, can control up to 2.5 million elements of data. Each front end can receive up to 70,000 I / O workloads points. The Client / SCADA server architecture allows operators to analyze in depth and distance data from the fields provided by the energies. Hence, they constantly monitor the situation and may take corrective action in time in case of failure

Each packet is delayed before it is transmitted on Radio channel for a time, which is equal to the time needed for transmission of the number of bytes set. This time depends on the set Modulation rate. To delay all packets for a time equals to the transmission time of a UDP packet with 150 users' data bytes, we need to set 178 bytes (20bytes IP header, 8 bytes UDP leader, 150 bytes user data).

The parameters that improve wireless communication in terms of RTT (Round-trip time), Bitrate, modulation [5], [6] and the End to End delay [7] have a vital role in real time control and command.

The Higher Modulation rates provide higher data speeds [5] but they also result in poorer receiver sensitivity, i.e. reduced coverage range. Reliability of communication over a radio channel is always higher with lower Modulation rates.

FEC (Forward Error Correction) is a very effective method to minimize radio channel impairments [5]. In principle, the sender inserts some redundant data into its messages. This redundancy allows the receiver to detect and correct errors (to some extent). The improvement comes at the expense of the user data rate.

Power quality is the ability of the supplied electricity on the distribution grid to adhere to root mean square (RMS) voltages systems, it can be commanded and controlled by several means such as Wireless Sensor network [8]. In this paper, we present a more efficient wireless communication method connecting two routers, in bridge mode, in order to forward the useful information of power quality in Wireless Renewable Energy Networks.

Based on this metric, we can see the effect of the modulation and FEC on bitrate/ forwarding time versus packet length. The User data rate = Modulation rate x FEC ratio.

As for the rest of the paper, it will be presented as follow. Section II explains the system model and the useful parameter of Power Quality controlled by the wireless network. The experimental setups will be described in Section III. The section IV evinces the experimental results. Finally, the authors conclude the paper in section V.

II. NETWORK

A. System model

The network model shows the different device construing the system, as presented in Fig. 1.

We considered a scenario with direct wireless transmission Bitrate (Kbytes)/Forwarding time (millisecond) from the source (A) to the destination (B) using Radio router (bridge mode) for forwarding messages (see Fig. 1).

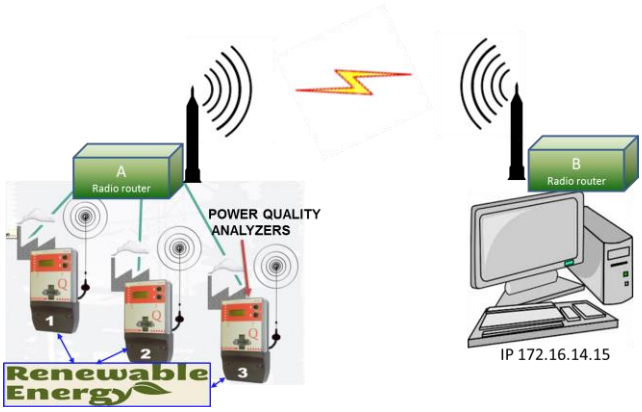


Figure 1. Network Model

Power Quality Analyzers are Equipment for measuring and recording the settings required for quality study of the sine wave to a determined measuring point. The QNA 412 / 413 are high performance power analyzers certified in accordance with Standard IEC-61000-4-30 (Class A) Testing and measurement techniques – Power quality measurement methods [9], which was introduced early 2003. They enable analysis of power quality (voltage, flicker, harmonic distortion, events, etc.) in any installation.

QNA works as a master making by itself a connection with an FTP server and keeping the information.

QNA sends the information to the FTP server making unnecessary make any call with a modem.

The Fig. 2 shows the update of Power Quality Analyzers (QNA) across the proposed wireless communication system.

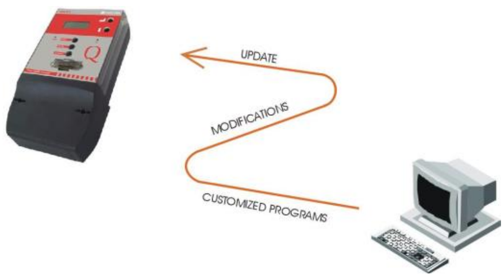


Figure 2. Remote Update

In a network based on packet switching, forwarding time is the average time in milliseconds to transmit a single packet between two Router units (or store-and-forward delay) in other words, this is the delay caused by the data-rate of the link. This delay is proportional to the packet's length in bits.

The message delay in the proposed communications is defined as the end-to-end delay between the two communicating end systems, (A) and (B) (see Fig. 1) including the message processing and transmission times at the source.

The forwarding time or delay is given by the following formula:

$$F_t = L / B \tag{1}$$

Where L: the packet length in bits and B: the data rate in bit/s (say in bits per second).

Most packet switched networks use store-and-forward transmission at the input of the link. A switch using store-and-forward transmission will receive (save) the entire packet to the buffer and check it for CRC errors or other problems before sending the first bit of the packet into the outbound link. Thus, store-and-forward packet switches introduce a store-and-forward delay at the input to each link along the packet's route.

B. Useful Information

The useful general information that we want to control and manage are:

1) Voltage variations and events.

Events according IEC 61000-4-30 and UNE-EN-50160 are presented in the Fig. 3.

Overvoltage: Increase of the RMS Voltage (half - cycle) in a determinate % of U_n from a programed level (f.ex. To 110 % U_n) during a time.

Voltage dips: Decreasing of the RMS voltage (half - cycle) between 90 and 10 % of the U_n during a time.

Interruptions: Decreasing of the RMS voltage (half - cycle) between 10 and 0% of the U_n during a time.

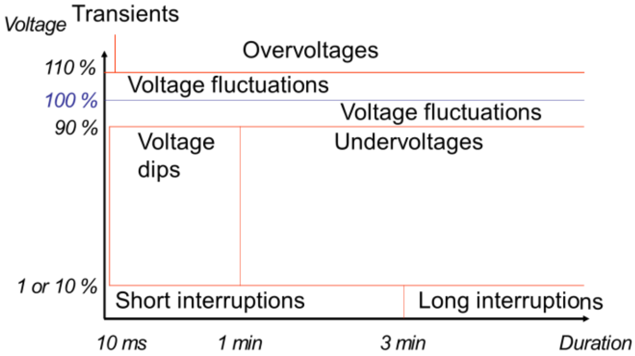


Figure 3. Continuity- Disturbance

2) Flicker (Pst, Plt)

The Flicker is defined as the subjective impression of the lighting blinking produced by power source fluctuations.

- ***Basic concepts***

- It is a modulation in low frequencies.
- Modulated frequencies: between 0.5 - 30 Hz.
- Modulation effects: It appears as a blinking in the lamps connected to that voltage. Produces an uncomfortableness to people.
- Human Eye Sensibility: More sensible in frequencies between 6 to 10Hz where flicker levels of 0,3 o 0,4 are perceptible

- ***Statistical analysis:*** P_{st}

P_{st} is expressed using probabilities in many periods. Flicker analysis, during a short period (IEC recommends periods of 10 minutes), is presented in the following Formula:

$$P_{st} = \sqrt{0.0314P_{0.1} + 0.0525P_1 + 0.0657P_3 + 0.28P_{10} + 0.08P_{50}} \quad (2)$$

where:

P_{st} : Short term flicker severity.

$P_{0.1}$: Flicker level present during 0.1 % of the time.

P_1 : Flicker level present during 1% of the time.

P_3 : Flicker level present during 3% of the time.

P_{10} : Flicker level present during 10% of the time.

P_{50} : Flicker level present during 50% of the time.

- ***Statistical analysis:*** P_{lt}

Flicker analysis during a long period (2 Hours) is given by the following equation

$$P_{lt} = \sqrt[3]{\sum_{i=1}^{N} \frac{P_{st_i}^{\;3}}{N}} \quad (3)$$

Where P_{lt} : Long term flicker severity

The Fig. 4, (A) and (B), show two typical examples of P_{st} and P_{lt} respectively.

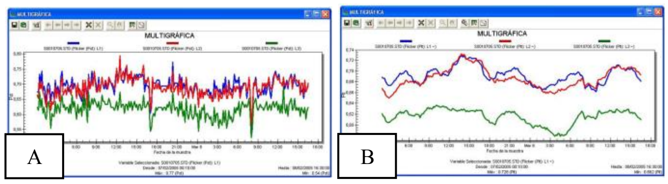
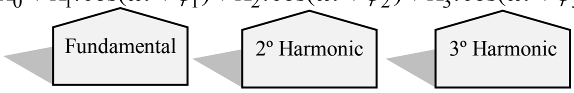


Figure 4. (A)Short Term Flicker Severity P_{st} . (B) Long-Term Flicker Severity P_{lt} .

3) Harmonics (individual and total harmonic distortion (THD)

Harmonic is defined as sinusoidal voltage or current with a frequency equal to an enter multiple of the fundamental frequency caused mainly by no lineal loads.

$$f(t) = A_0 + A_1.\cos(\omega t + \varphi_1) + A_2.\cos(\omega t + \varphi_2) + A_3.\cos(\omega t + \varphi_3) + ...$$



Main harmonics: up to nº 15, specially 3th, 5th, 7th, 11th and 13th

$$U_n \% = U_n / U_1.100; I_n \% = I_n / I_1.100$$

Standard IEC-61000-4-7 and EN50160, 95 % of the RMS values averaged every 10 ms (by harmonic) must be lower or equal to the values that appear in the following table I (1-week period).

TABLE I. ODD AND EVEN HARMONICS

Odd harmonics		Even harmonics	
Arm N°	% V_n / V_1	*Arm N°*	% V_n / V_1
3	5 %	2	2 %
5	6 %	4	1 %
7	5 %	6….24	0.5 %
9	1.5 %		
11	3.5 %		
13	3 %		
15	0.5 %		
17	2 %		

The Fig. 5 represents the curve of the harmonic.

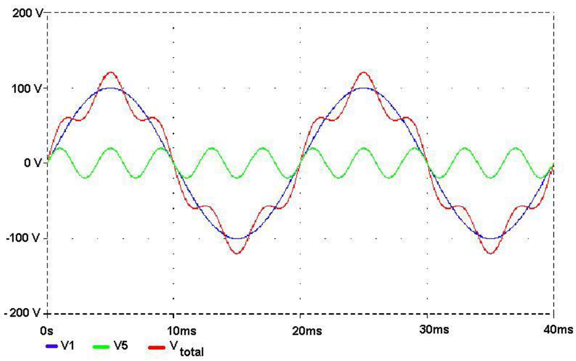


Figure 5. Main Harmonics.

Harmonic component (n): relation between harmonic frequency (f_n) and fundamental frequency (f_1).

The Fig. 6 shows example of the THD analysis

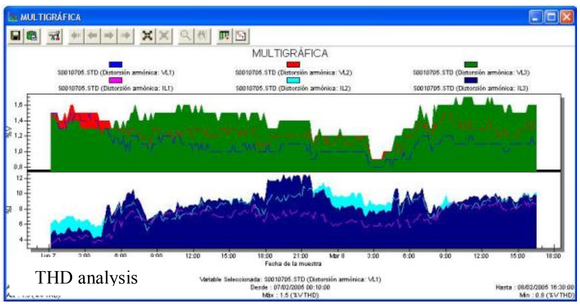


Figure 6. THD Analysis.

Total Harmonic Distortion (THD) (U_n % or I_n %): % relation between RMS value of voltage and current and its fundamental component.

4) Unbalance

Voltages are rarely balanced between phases. However, when voltage unbalance becomes excessive, it can create problems for poly-phase motors and other loads. Moreover, Adjustable Speed Drives (ASD) [10], [11] can be even more sensitive than standard motors.

Voltage Unbalance is defined by IEEE as the ratio of the negative or zero sequence components to the positive sequence component. In simple terms, it is a voltage variation in a power system, in which the voltage magnitudes or the phase angle differences between them are not equal. It follows that this power quality problem affects only poly-phase systems (e.g. three-phase). It may be below to 2% for 95% of week, mean 10 minutes RMS value.

III. EXPERIMENTAL SETUP

A. Operating Mode

Bridge mode is the configuration that disables the Network Address Translation (NAT) feature on the modem and allows a router to function as a Dynamic Host Configuration Protocol (DHCP) server without an Internet Protocol (IP) Address conflict. The modem has to be bridged before connecting to a router since applications like Virtual private network (VPN), Peer-to-peer (P2P), and remote management require a public IP Address on the router Wide Area Network (WAN) port for a successful connection.

In this experimental application, we use the router in bridge mode to connect multiple devices wirelessly.

Bridge mode is suitable for Point-to-Multipoint networks, where Master-Slave application with polling-type communication protocol is used. Router in Bridge mode is as easy to use as a simple transparent device, while allowing for a reasonable level of communication reliability and spectrum efficiency in small to medium size networks.

In Bridge mode, the protocol on Radio channel does not have the collision avoidance capability. There is CRC check of data integrity, i.e. once a message is delivered; it is 100% error free.

The whole network of router (bridge) units behaves like a standard Ethernet network bridge, so the Ethernet interface IP address itself is not significant. Each ETH interface automatically learns that the devices (MAC addresses) lie in the local LAN and the devices are accessible via the Radio channel. Consequently, only the Ethernet frames addressed to remote devices are physically transmitted on the Radio channel

All the messages received from user interfaces (ETH&COM's) are immediately transmitted to Radio channel, without any checking or processing.

Each Router may work simultaneously as a Repeater (Relay) in addition to the standard Bridge operation mode. In this case, every frame received from the Radio channel is transmitted to the respective user interface (ETH, COM1,2) and to the Radio channel again. The Bridge functionality is not affected, i.e. only frames whose recipients belong to the local LAN are transmitted from the ETH interface.

It is possible to use more than one Repeater within a network. To eliminate the risk of creating a loop, the "Number of repeaters" has to be set in all units in the network, including the Repeater units themselves.

B. *Advanced parameters*

Router in bridge mode, used in this paper, allows multiple settings of modulation parameters for every channel spacing to enable meeting the different regulations applicable in different countries. Naturally different limits on transmitted signal parameters result in different Modulation rates.

The "Mode" menu conveniently groups the settings optimal for common internationally recognized standards.

Note: In the 25kHz channel spacing (Narrow band), the router transmitted signal 16 kHz bandwidth contains 99% of the total integrated power for transmitted spectrum according to ITU-R SM 328 [12].

C. *Power studio: Energy management software*

This software allows the user to monitor the installation by staying informed in real time the status of its power lines and its overall consumption, as low in medium voltage. This supervision is very important to get accurate information about the state of the electrical system, the data proving fundamental to making good decisions. According to the equipment specifications installed, a large number of electrical parameters and process can be monitored.

D. *PowerStudio SCADA*

Due to the large volume of information provided by each data logger, a centralized data collection system is needed.

SCADA Power Studio is designed to fill the centralizing function and information manager. Furthermore, it is developed so that any user can create its own custom screens. The ultimate goal of this software lies in data processing and reporting in order to take preventive or corrective action on installation, why CIRCUTOR has developed this complete energy management software. Ultimately, this software allows the integration of CIRCUTOR equipment to carry out their management (QNA network analyzers, energy meters CIRWATT, protective equipment, etc.). Moreover, all these facilities are likely to be incorporated by any other market SCADA system, since the protocols they use are completely standard and explicitly comply with regulations relating to communication (Modbus / RTU, Modbus / TCP, Profibus-DP, Johnson Controls or XML).

The QNA configuration is very useful if the customer wants to communicate from different host or wants to integrate in a SCADA system. Through the implementation used in this paper the customer calls to the device using a modem and download data.

E. *Experimental parameters*

Routers setting such as modulation mode, FEC and so on are summarized in the table II.

TABLE II. EXPERIMENTAL PARAMETERS

Radio parameters	**Technical specification**
Operating mode	bridge
Bandwidth	Narrow Band
Channel spacing (Khz)	25
Modulation rate(kbps)	83.33|16DEQAM, 41.67|pi/4DQPSK, 20.83|4CPFSK
FEC	3/4
Power Quality Analyzers	QNA 412

IV. EXPERIMENTAL RESULTS

The following Figures show how Bit rate and Forwarding time vary in terms of different messages size (0 up to 1500 bytes) of one-hop with (FEC 3/4) and without (FEC 3/4) respectively. On the following figures, we can clearly notice the uses of SCADA system, such as:

A. *Bit rate vs average message size*

The following figures show the effect packet length has on the resulting bitrate using different modulation type and with /without FEC.

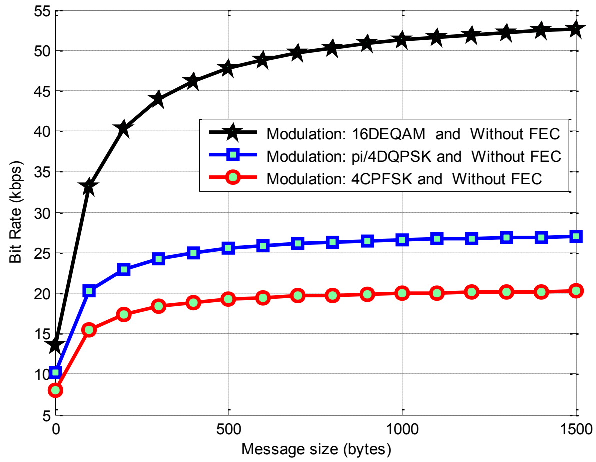


Figure 7. Evolution Of Bit Rate For Modulations Without FEC

The Fig.7 illustrates the evolution of bit rate for modulations [16DEQAM, pi/4DQPSK, and 4CPFSK] without FEC. In this figure, we observe that the curves modulations [16DEQAM, π / 4DQPSK, 4CPFSK] without FEC when they rise, the message size will also increase with an important and positive change of the bit rate (kbps).

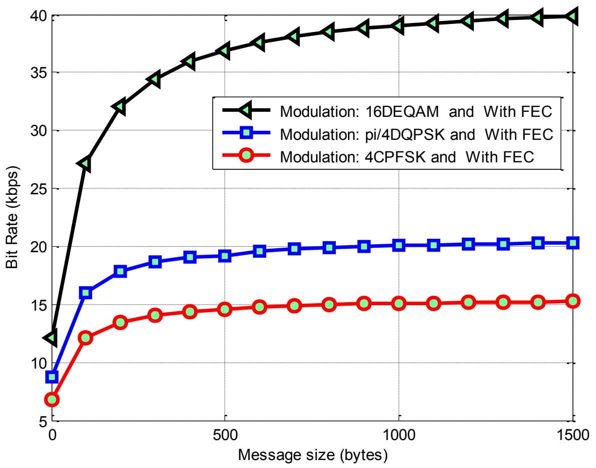


Figure 8. Evolution Of Bit Rate For Modulations With FEC

The Fig. 8 illustrates the evolution of bit rate for modulations [16DEQAM, π/4DQPSK, and 4CPFSK] with FEC. We should note that in the above figure the increase of the curve that shows the modulation with FEC 16DEAQAM by increasing the bit rate (kbps).

The same for the other curves except that the 4CPFSK modulation with FEC will have a message size once it has a 15 kbps as a bit rate.

The Fig. 9 shows the comparison between measurement results of bit rate average for two-modulation type with and without FEC

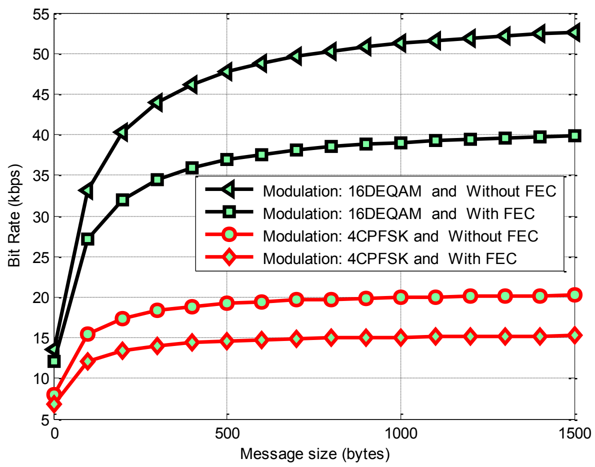


Figure 9. Comparison Between Measurement Results Of Average Bit Rate For Modulation With And Without FEC

In light of the results obtained on the shade of this application, it can be concluded, in Fig. 9, that modulation 16DEQAM without FEC has a remarkable improvement on bit rate versus message size.

Based on the results found, the most important concluding notes can be seen in the following:

- The bit rate increases considerably when the message size (bytes) increases.
- The modulations [16 DEQAM & 4CPFSK] without FEC have a positive effect on reducing bit rate (kbps) measurements.

The modulations [16 DEQAM & 4CPFSK] with FEC have an important effect with improving the bit rate (kbps) and having the scalable message size (bytes).

B. One-hop Forwarding time vs average message size

The following figures illustrate the effect packet length has on the resulting Forwarding time (FT) using different modulation type with /without FEC respectively.

The Fig. 10 gives results FT vs. message size for tree modulation type.

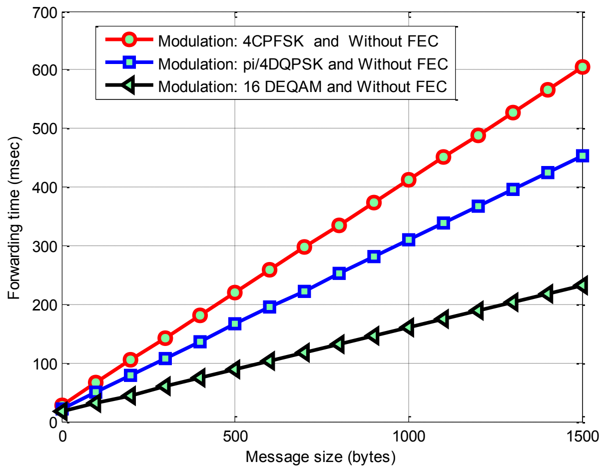


Figure 10. Evolution Of Forwarding Time For Modulations Without FEC

In Fig. 10, FT increases when the packet length increases using different modulations type without FEC.

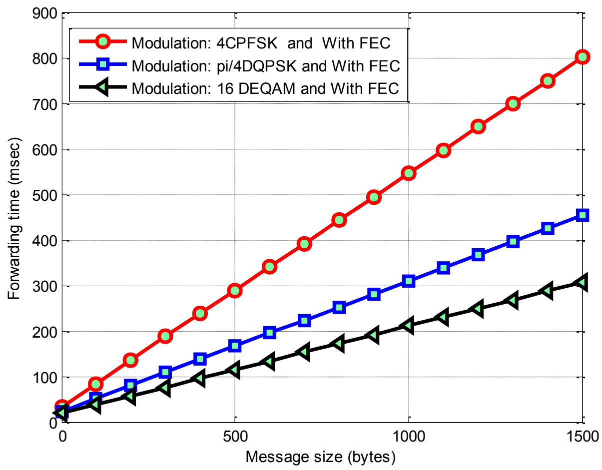


Figure 11. Evolution Of Forwarding Time For Modulations With FEC

In Fig. 11, FT increases when the message size increases, the introduction of FEC= 3/4 can also promote a slight decrease in FT.

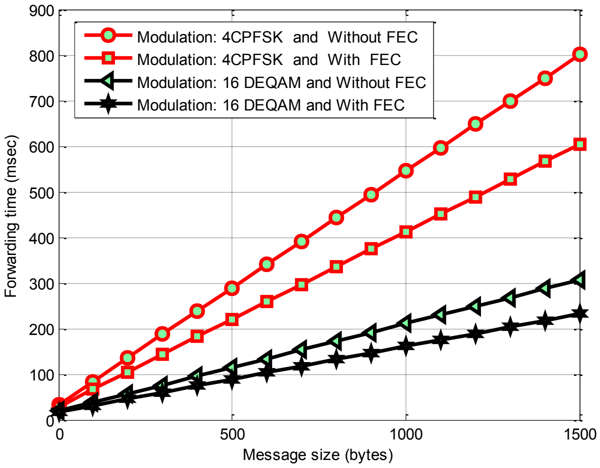


Figure 12. Comparison Between Measurement Results Of Forwarding Time For Modulation With And Without FEC

The comparison measurements in Fig. 12 show that the modulation 16DEQAM with FEC has a remarkable improvement on forwarding time versus message size

V. CONCLUSION

The present paper intendeds to give a new quick metric performance overview for wireless network based on several basic parameters, results show.

The modulation mode has an influence on Payload bitrate /Forwarding time versus Average message size. When the baud rate of each modulation type increases the payload bit rate increases and FT decreases with different values that may take message size. In addition, the introduction of (FEC 3/4) it has a significant influence on Bite rate and FT. We can increase bite rate and FT without FEC and decrease them with FEC.

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