Research Article

An effective practical method for narrowband wireless mesh networks performance

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Abstract

This study presents a new practical measurement method for analyzing narrowband wireless mesh networks (NWMNs) application performance. It investigates a scenario for packet transmissions in NWMNs, leveraging wireless interconnection between two devices. It analyzes the effect of message size and channel spacing on the resulting bitrate, forwarding time and modulation rate through experimental results. We transmit a single packet for one hop, exploiting a versatile radio modem with very-high-frequency radios operating in the bridging or routing modes. The measurement results obtained, with the mentioned critical operating parameters, provide a quicker and clearer idea as well as conclusive evidence for overall network performance.

Keywords Narrowband wireless mesh networks · Radio modem · Wireless communication

1 Introduction

Narrowband wireless mesh networks (NWMNs) [1] are emerging technologies that provide connectivity to control, manage, supervise, and offer more capacity to devices in critical applications. In mesh networks, any node-connect haphazardly and spontaneously to each other. NWMN furnishes a more advantageous distance per watt of power consumption than broadband. Several types of research have been carried out in the field of narrowband. In the field of optical communication systems, Bragg gratings are used to provide narrow-spectrum filters [2]. The paper presents an experimental analysis of a narrowband wireless mesh network, using one-hop forwarding time, payload bitrate, message size, modulation, ACK, channel spacing, payload bitrate, and maximum transmission unit (MTU) as evaluation parameters. In this paper, the users of narrowband radio data modems are supervisory control and data acquisition (SCADA) operators, telemetry operators, among others.

Radio modems offer the best solutions for the wireless transmission of many short messages, which is studied in [3], where guaranteed delivery is necessary. Most radio modems are remotely configurable and manageable. In the broadcast industry, they use narrowband (NB) technology with channel spacing of 6.25, 12.5, and 25 kHz, according to the European Telecommunications Standards Institute (ETSI), ETSI EN 300-113 standard [4].

Recently, (ETSI 300-422) [5] it became possible to use 50 kHz on 470 MHz, which constitutes a good combination between the economy of the frequency and the quality of the audio. Generally, in wireless mesh networks, the communication system operates on frequencies between 30 MHz and 1 GHz using channel separations up to 50 kHz, which has been elected and adapted to various radio packet switching networks. It should be noted that the industrial radio equipment covered in this document has

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been subjected to [4]. On the other hand, the authors of the article [6] analyzed statistically and experimentally the propagation of NB waves at 2.4 GHz.

In the bridging mode, the received packets are transparently broadcast on all units without any checking or processing, whereas the router mode works as a standard internet protocol (IP) router. The bridge mode is appropriate for point-to-multipoint networks, and it is as easy to use as it is to manage. Moreover, it is as facile to exploit for the simple and transparent device while permitting an acceptable level of wireless communication reliability.

Depending on the application type, two different radio protocols (i.e., flexible and base-driven) are available to give greater performance. Even under severe radio channel interference conditions, these protocols avoid collisions and use retransmissions, cyclic redundancy checks, and acknowledgments (ACKs) to ensure data transmission and integrity. These protocols can also send unicast frames to a specific device and address broadcast frames to everyone on the local network [7].

The transition to NB CS (NB channel spacing) or the commercial radio band that is reduced from 25 to 12.5 kHz has been dictated by the increasing demand for radio frequencies [8] made to the Federal Communications Commission, which imposed this new separation on very high frequency (VHF) radio frequencies of 154–174 MHz. It can be used in the case of very complex propagation problems as in [9].

To determine whether a connection is established in wireless networks, it is important to measure average message size, payload bitrate, and transmission time [10, 11]. Wireless mesh networks cooperate to enhance the efficiency of the progressive communications planned for customized SCADA systems [12] because this type of network uses coding [13] where all radio modems can randomly access each other [14].

In this paper, we use various critical parameters [e.g., one-hop forwarding time, payload bitrate depending on message size, modulation, forward error correction (FEC), ACK, payload bitrate, and maximum transmission unit (MTU)] to measure simple router/bridge radio network performance. We focus on real operational wireless networks with two fixed nodes, or the other performances are measured in terms of bit error rate versus signal-to-noise ratio [15] for remote control applications of the industry such as SCADA and telemetry, electricity, weather, smart grid, outlets, and ATMs.

The paper conducts a novel investigation and uses the fast method to detect the performance of NB wireless mesh networks (NWMNs) by identifying and varying the critical parameters.

The rest of the paper is organized as follows. Section 2 is a review of the studies related to the practical proposed method. Technical and operating parameters are described in Sect. 3 with physical values. The systems model is introduced in Sect. 4. Section 5 describes the experimental setup and results and discusses the obtained wireless bridge/router mode measurement results. Finally, conclusions are offered in Sect. 6.

2 Related works

The data and message size, payload bitrate, modulation, ACK, channel spacing, payload bitrate, and maximum transmission unit, in Narrowband Wireless Mesh networks, play a vital role in improving service quality performance.

The practical notion of the effect of data size has been addressed by Ar-reyouchi et al. [9]. They analyze the effects of Acknowledge and Forward Error Correction on the practical transmission performance of different message sizes. In [16, 17], several measurements are carried out in comparison to different values of packet length and baud rates, and the authors analyzed the performance of practical network topology in wireless communication based on Narrowband RF Networks. They showed how a round trip delay evolves over the packet length according to different modulation rates without FEC and with FEC, respectively.

The authors in [10] experimentally demonstrated that the data size has a great effect on forwarding time, which is increased when the packet length increases. The research paper in [18] studies the consequence of packet size on concluding bitrate characteristics in a wireless real-time application using narrowband RF mesh technology.

The authors in [19] have studied the impact of message size on the average delay in a wireless real-time application based on packet switching. They have also clearly illustrated experimentally the relationship between modulation type, channel spacing, forwarding time, and data length based on average message size.

While in [20], the effect of the Downlink and Uplink message size on round trip time has been experimentally shown. This effect is treated with and without forwarding Error Correction (FEC) between a Supervisory Control and Data Acquisition (SCADA) center and a destination RTU (Remote Terminal Units).

3 Technical parameters

This paper provides an overview of router radio network performance using the supervisory system for the management of IoT devices and remote terminal units (RTUs). The novel metrics proposed are used to measure critical process parameters (e.g., modulation, bitrate, forwarding time) and critical quality attributes that give quick and easy metrics of the router's wireless performance. We note that the experiment does not capture the multi-hop nature of the communication, but only a single link is studied.

3.1 Modulation

Router radios allow multiple modulation settings for all CSs to enable different regulations. Naturally, different modulation speeds are driven by different limits on the parameters of the transmitted signal.

It should be noted that continuous-phase frequency-shift keying modulations have a nearly 20% higher frequency deviation compared to the European Commission (CE) standard. Thus, the receiver sensitivity for the same modulation (data rate) is approximately 1–2 dB better. As reported by ITU-R SM328, the 16 kHz bandwidth of the signal sent by the router consists of 99% of the total integrated power of the transmitted spectrum in the 25 kHz CS.

Regarding linear modulation techniques, the differentially encoded formats (π/4-DQPSK, D8PSK, and 16-DEQAM) have been affected for signal propagation exploiting the narrowband radio channel. On the other hand, the modulation index is one of the most efficient parameters that can influence 2CPFSK and 4CPFSK modulation format identifications, which are the preferred choice of the nonlinear modulation family. The general relationship between the modulation rate and the maximum frequency deviation is:

$$h = 2\Delta f / R(M - 1),$$

where R is the modulation rate, M is the number of modulation states, Δf is the maximum frequency deviation representing the outermost symbol frequency position.

Frequency-shift keying (FSK) is a frequency modulation family of nonlinear modulations. The use of quadrature amplitude modulation (QAM) has the advantage of being a higher-order modulation form, which can, therefore, carry more bits per symbol. However, QAM is widely used for communication monitoring; this modulation is appropriate for normal conditions and provides a higher data rate. These types of modulations need the possibility of using a higher radio frequency (RF) output power.

3.2 Forward error correction (FEC) technique

FEC is identified as a coding technology commonly employed in communication systems. In WLAN or WiMAX networks, for example, the traditional version of the FEC technique can increase the efficiency of round-trip times in single-hop wireless networks [21]. The use of the FEC approach [22] allows the source code to add information with the data before distributing it to the receivers, which means that the transmitter introduces redundant data into his messages, which allows the receiver node to detect and correct errors within digital transmissions. These can recover the amount of data loss, if it is small enough, using various decoding schemes [23]. FEC is also advantageous in terms of method efficiency for decreasing radio channel deterioration.

It is necessary to mitigate the errors caused by the radio channel. If we consider that b is the modulation rate, the user data rate is $D = b \times FEC$. The useful data rate is usually less than the actual data rate provided by the network.

3.3 Acknowledgment (ACK) code

The sending of acknowledgment by the receiving router in the correction by the retransmission technique is necessary. The reception of the small service packet, ACK, over the radio channel serves to indicate that it has successfully received the packet. If an acknowledgment is not received, the router retransmits the packet based on a given number of attempts.

It should be noted that the ACK settings need supplemental bandwidth for retransmission of lost or corrupted frames [20]. The transmitting packet sizes are not necessarily fixed; they can have variable sizes, depending on the type of network and its protocol.

If t_e is the probability that a bit transmitted is wrong and $(1 - t_e)$ is the probability that a bit is correctly transmitted, the probability that the ACK is successfully transmitted is $P_r = (1 - t_e)^K$ where K is the ACK bit.

It is needless to receive an ACK from the destination node when the packet is transmitted only once and without repetition. Moreover, in wireless mesh networks, the ACK retransmission is an essential element of the radio protocol. It can operate separately from the attempts performed at higher protocol levels using the highest data transfer.

3.4 Payload bitrate

The binary information, transmitted by a channel, has a relationship with packet transmission time and packet size, which affects network performance. The payload of essential data is routed into a packet or other transmission unit. The payload does not include the "extra" data needed to route the packet to its destination. Each packet, regardless of its size, is structured by a header, including its source and destination IP addresses. The payload bitrate of custom IP packets transmitted by routers on the radio channel includes 28 B of IP packet overhead, 20 B of IP header, and 8 B of user datagram protocol (UDP) header. However, this study assumes that UDP is the layer-4 protocol.

3.5 Maximum transmission unit (MTU) parameter

The size of the packets is limited [24]. On a data communication link, the packet size is in bytes, and the MTU is the largest packet size that can be transmitted over a network. For most Ethernet networks, this is set to 1500 B; this size is used almost universally on access networks. Work presented in [25] proposed two algorithms (i.e., optimum and simplified) to find one optimum MTU for all messages in the scope of the single-switch flexible time-triggered-SE [26] protocol. Later, a heuristic algorithm [23] was proposed in the same context. As illustrated in [16], the MTUs vary according to the category of protocol and network, while the payload varies from 40 to 1500 B. The payload size to the maximum frame size is known as the protocol efficiency, which is the ratio of payload to the frame size.

The mission of the application implementation is to integrate the network analyzer by illustrating the effect of packet size, carrier spacing, and modulation rate on the performance of wireless mesh networks through experimental results. Since the overhead of the packet radio protocol is fixed, the length of the user data measurably affects the bitrate of the payload. Based on the present study, the effect of packet length can be measured, as in [18], on the resulting bitrate. In the case where the transport control protocol (TCP) is used, the resulting bitrate will be lower because of the higher TCP overhead. Other projects have optimized communication for TCP proxy functionality.

4 Systems model

To transmit on one frequency and receive on another simultaneously, a common configuration for NB telemetry is full-duplex. The system model is divided into two network topologies: transmission across the internet and transmission through routers. In this work, we are interested only in the second topology. We are targeting the first topology for future work.

The forwarding time, exploring a one-hop link, is the average time (ms) needed to transmit a single packet between two radio router units (see Fig. 1). It requires packets to be processed, switched, and queued. The packet transmission time P_{TT} in seconds (on a radio channel) can be calculated from the packet size P_S [23].

The bitrate B_r in b/s is: $B_r = \frac{P_{TT}}{P_S}$.

4.1 Operating wireless router mode

We designate a direct one-hop path from the node *A* to node *B*. A practical illustration of the router configuration transmitting a single packet from IoT's main radio modems to IoT RTU. More specifically, the original message (from IoT SCADA center) arriving at a node A, eventually, after being passed through various routers via Internet network, as is shown in Fig. 1.

As illustrated in Fig. 1, the IoT SCADA center allows operational management of where the technical connection is provided via an Internet. The IoT SCADA center sends requests one-by-one to RTU1. Packets coming from the SCADA center are transmitted to internet networks. The IoT main radio modem is duplex, and the transmission carrier is on all the time while the SCADA center sends and

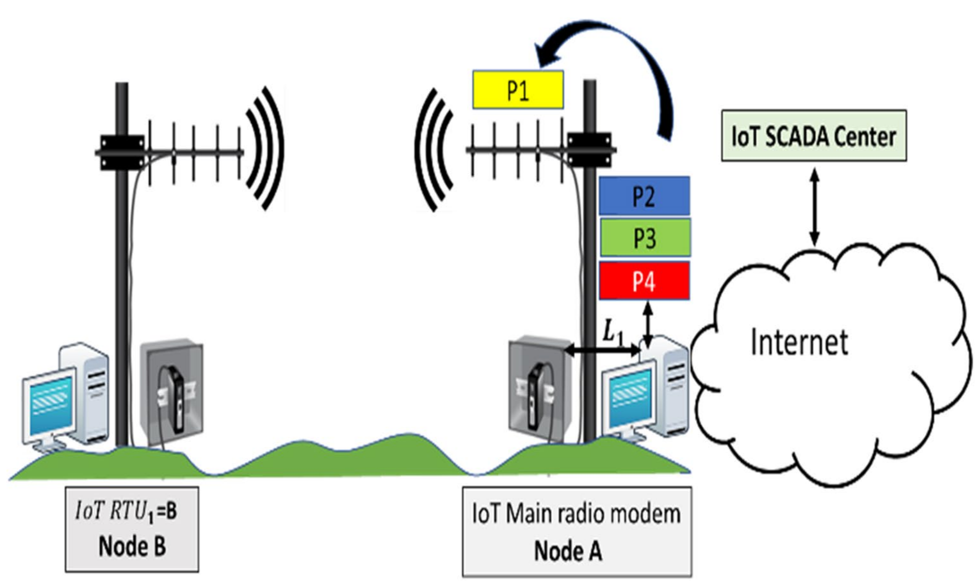

Fig. 1 Performance for packet-switched network

receives the packets. The IoT SCADA center sends requests one-by-one to RTU1 employing internet and IoT main radio modems. The proposed operating system model shown in Fig. 1 has ranges that exceed 50 km.

Suppose all packets of the same message take the same route, as illustrated in Fig. 1. Assuming that the transfer time on and the processing time are zero, only the time of transmission of the packets on the medium intervenes to determine the performance.

We consider a single packet traveling from the node *A* to node *B*. Transmitters using digital modulation shall have a link arriving at a bitrate of, at least, 4.8 kbps at a bandwidth of 6.25 kHz or a voice channel at a bandwidth of 12.5 kHz. The message size $L(b)$ is constituted of *p* packets, transmitted on the different wireless transmission mediums conserving the same rate: *D* bit/s.

Suppose the node *A* begins transmitting a packet P_1 at the time $t = 0$ over the link L_1. The node *B* receives this packet $t_0 + t_p$, where t_p is the transmission time of the packet.

Assume that the processing time in the node is 0. The packet is re-transmitted immediately on the node *B*, while packet 2 is transmitted on L_1.

If N is the number of nodes, packet 1, P_1 reaches the destination node at $(N + 1)\ t_p$, and if p is the number of packets, the last packet sent is $(p - 1)t_p$. The last packet arrives at $(p - 1)t_p + (N + 1)t_p$ corresponding to the end of the transfer. Again, $t_p(p + N)$. Given $t_p = L/pD$, we obtain the crossing time of the network T_p, $T_p = (L/pD)(p + N)$, or:

$$T_p = (L/D)(1 + N/p) \tag{1}$$

However, this formula does not consider protocol data H, which should be added to each package. Thus,

$$T_p = \left(\frac{L + pH}{D}\right)\left(1 + \frac{N}{p}\right) \tag{2}$$

The transit time in the network is even lower than the smallness of factor N. The influence of the service header size is not negligible.

4.2 Operating wireless bridge mode

Bridges are used to overcome line-of-sight blockages in radio paths or to extend radio range. Bridge mode is adapted for master–slave relationships. Their IP addresses concern local, remote controlled or telemetry units. (e.g., IoT SCADA center-IoT RTU) practicing a polling-type application protocol (see Fig. 2).

Any unit can be configured as a repeater when it is in bridge mode. A repeater is intended to relay all received packets through the radio channel, but it is also used as a simple device by offering a suitable and practical level of communication and spectrum efficiency in the small or medium wireless network size. In bridge mode, the expected system throughput, (*D* (kb/s), is defined as the amount of data transferred in a time interval, t, divided by the duration *t* when *t* approaches infinity:

$$D = \lim_{t\to\infty}(\,p(t) \times packet\_lenght)/t,$$

where $p(t)$ gives us the number of packets transmitted in the system, and packet length is the size of the packets, assuming they are all equal. Notice that the number of packets, $p(t)$ divided by t, is equal to the inverse of expected packet service time when *t* approaches infinity. Therefore, $D = packet\_lenght/T$ where T is the average transfer delay, excluding the random-access phase that takes place before the uplink channel assignment. However, it should be noted that the number of binary information entities, that a channel can send per unit time is: $\lambda = N_p/T$ where N_P is the average number of packets in the

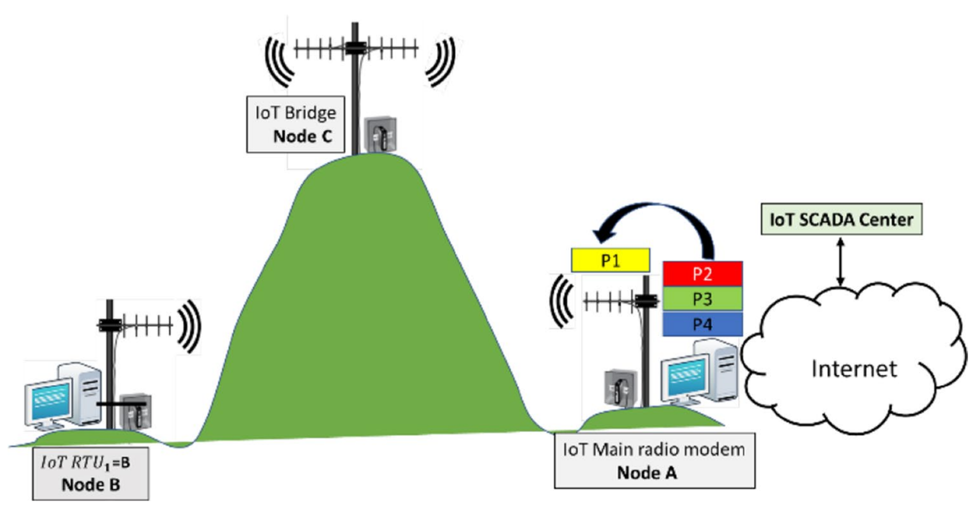

Fig. 2 Bridge diagram

system, T is the average amount of time a packet spends in the system, and λ is also the arrival rate of packets.

The size of the answering frame, the length of the radio protocol overhead, and the modulation rate should be considered.

5 Results

The results of this paper are based on performance measurements of the wireless mesh network, which are important not just for conferring a fast performance overview but also for ensuring the successful operation of the user application.

5.1 Experimental setup

The executed system is formed by two parts: related hardware and management software. The executed system is formed by two parts: related hardware and management software.

The wireless communication system is halved in devices and intercommunicating devices. The devices of a system (hardware) include a data monitoring unit, a monitoring center, and a wireless transmission unit, while the other part of the system (software) adopts the users with basic information and configuration management, fault statistics and records, real-time monitoring system, maintenance reminders, etc.

The hardware and software include an omnidirectional KA160.3 antenna that is designed for radio base stations included in the 158–174 MHz bands. The radiation pattern of the transmitting antenna is omnidirectional, with a gain of 3 dB. It also provides a variable output power of the radio router between 0.1 and 10 W, and the values received at each site vary between 38 and 70 dBμV. The processing time is the time needed for the IoT devices to process queries. The radio modem in nodes A and B have the same interface speed and the same value. Table 1 lists the technical parameters selected for this experimental study.

Table 1 Default radio parameter settings

Radio parameters	Condition chosen
Frequency bands	154–174 MHz
CS	6.25/12.5/25/50 kHz
Operating mode	Router/or—and/bridge
Modulation schemes	Linear (QAM): 16DEQAM, D8PSK, π/4DQPSK, DPSK exponential (FM): 4CPFSK, 2CPFSK
ACK	On
FEC	Without
RF power (w)	1–10

5.2 Results presentations

This subsection provides an overview of the observational results and presents major findings concerning the experiment objectives.

5.2.1 Wireless router mode measurements

The model illustrated in Fig. 2 is followed. The results of payload bitrate versus channel spacing are shown in Fig. 4, and those of the transmission time concerning the average size of the messages is illustrated in Fig. 5.

5.2.1.1 Payload bitrate Payload bitrate of one-hop wireless mesh networks for various packet sizes is shown in Fig. 3.

According to the results in Fig. 3, the payload bit rate increases as the CS values increase. Also, it is found that, when increasing the message size, the payload bitrate increases significantly.

The curves in Fig. 4 illustrate the payload bitrate evolution for various packet sizes and CS ranging from 6.25 to 50 kHz.

The effect of the various packet sizes over network payload bitrate can be observed in graphical format in Fig. 5. Initially, as the packet size increases, the payload bitrate increases until it achieves a 1500-bit packet size. Thus, the spacing channel has a significant impact on network performance.

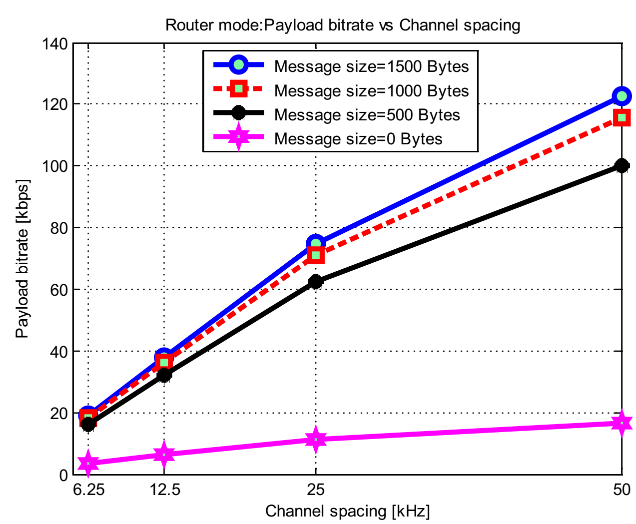

Fig. 3 Payload bitrate (kbps) versus CS (kHz) for different fixed message sizes

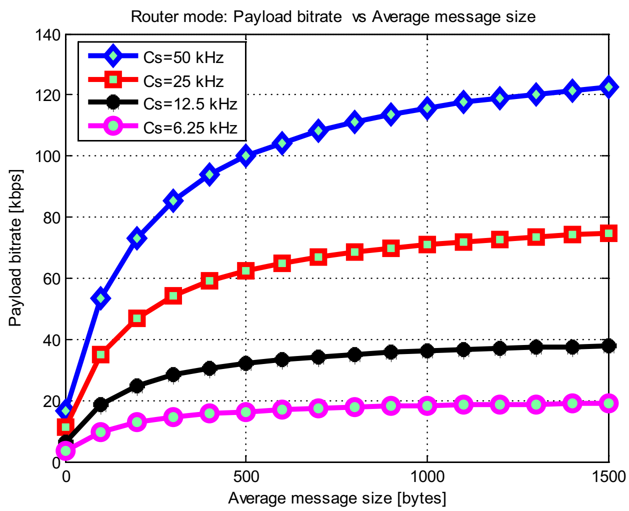

Fig. 4 Message size impact on payload bitrate depending on the spacing channel

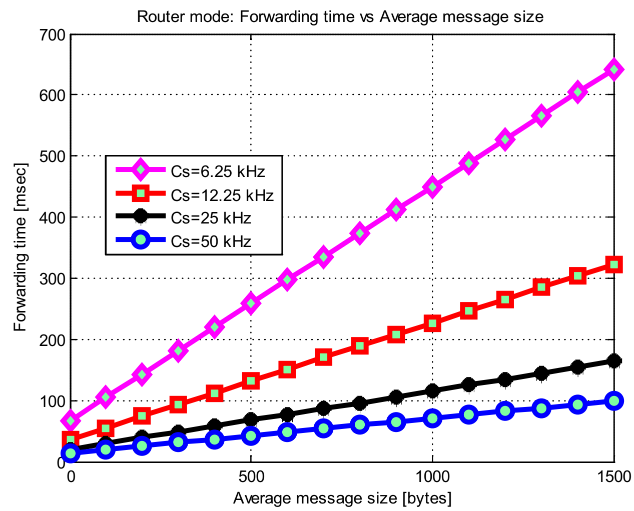

Fig. 6 Representation of the transmission time (ms) for a connection to a hop compared to the medium message router mode

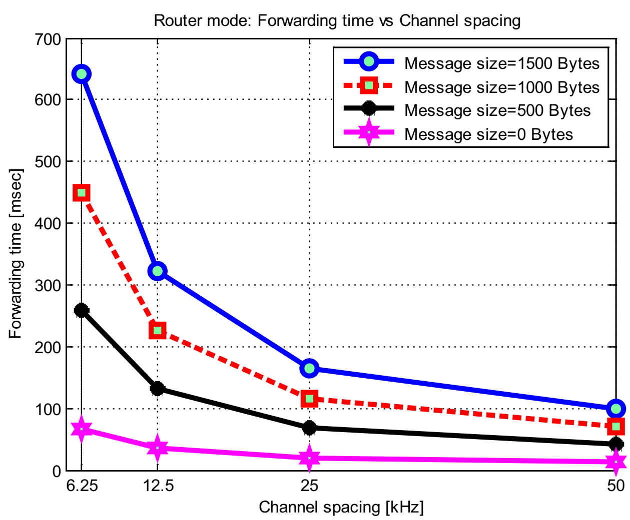

Fig. 5 Forwarding time (ms) versus CS (kHz) for different fixed message sizes

5.2.1.2 Forwarding time between two distant nodes, one-hop Figure 5 shows the curves of one-hop forwarding time repartition among average message size values for different CSs.

Execution forwarding time measurement is done with varying CS to transmit a single packet to quantify the effect of NB on message size. As shown in Fig. 5, the forwarding time decreases as CS increases. From CS = 25 kHz, there is a slight increase in the forwarding time.

Figure 6 illustrates how the forwarding time varies, depending on the average message size, according to the fixed CS.

The transmission time increases linearly for the average size of the message, as illustrated in Fig. 6. The comparison measurements in Fig. 6 show that the Cs = 50 kHz has a remarkable improvement in average time versus average message size. Furthermore, the above results can reveal that channel spacing of 50 kHz has a remarkable impact on reducing average message time (ms) with reference to channel spacing Cs = 6.25 kHz, Cs = 12.5 kHz, and Cs = 25 kHz.

Once again, it should be noted, however, that the maximum IP average message size is based on the link MTU for the Layer 2 technology.

5.2.2 Wireless bridge mode measurements

The full model is shown in Fig. 2 is used using the bridge model. The results of the payload bitrate/forwarding times versus CS/message sizes are shown in Figs. 7, 8, and 9.

5.2.2.1 Payload bitrate Figure 7 compares the payload bitrate versus the CS of the node *C*(bridge node) between the two static nodes (*A* and *B*) by setting different message size values. Bridge only forwards packets between node *A* and node *B*(RTU1 and main radio modems see Fig. 2).

From the results shown in Fig. 7, it is possible to observe that the payload bitrate increases as the CS values increase. The bitrate of the payload is visibly increased depending on the increase in message size. This rate can then be improved thanks to the bridge mode with the channel and the average size of the messages involved. The curves in Fig. 8 illustrate the payload bitrate evolution as well as and bridge mode for various packet sizes and CSs ranging from 6.25 to 50 kHz.

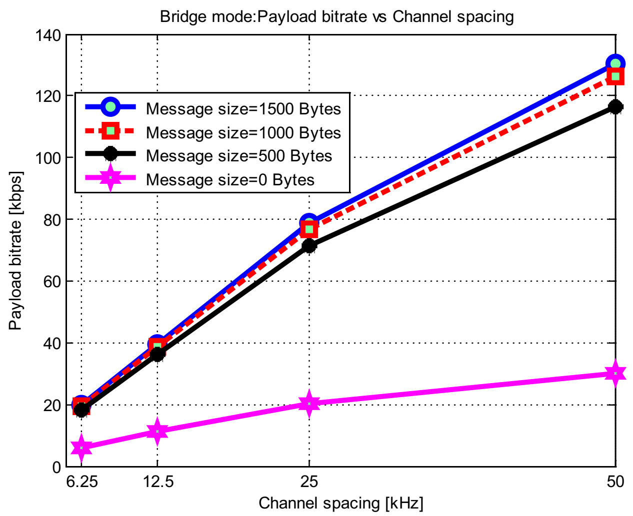

Fig. 7 Payload bitrate (kbps) versus CS (kHz) for different fixed message sizes

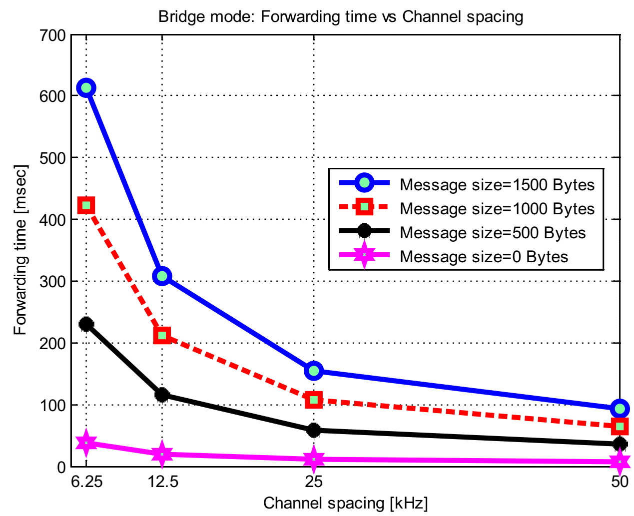

Fig. 9 Forwarding time (ms) versus CS (kHz) for different fixed message sizes

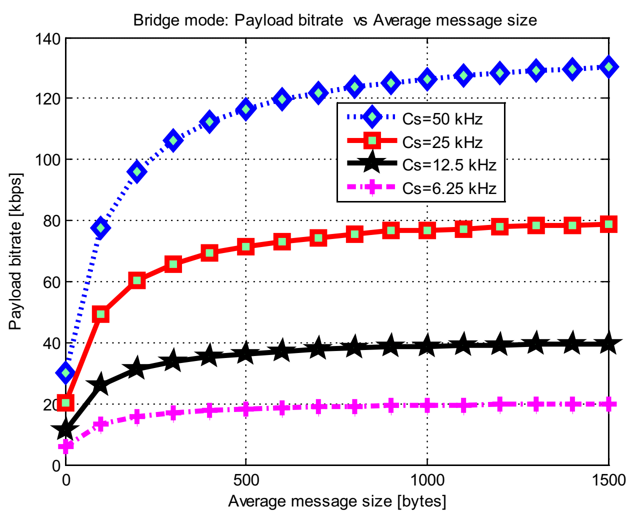

Fig. 8 Message size impact on payload bitrate depending on CS

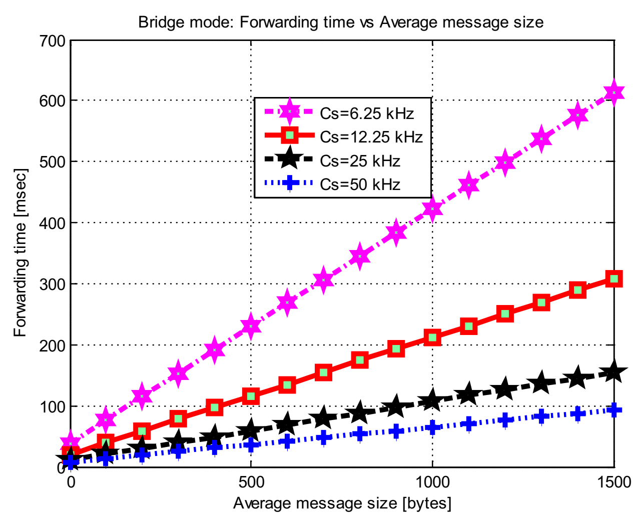

Fig. 10 Forwarding time (ms) for one-hop connection versus average message size

As seen in Fig. 8, the payload bit rate increases significantly with CS = 50 kHz, and CS = 25 kHz increases slightly with the following channels spacing: CS = 12.5 kHz and CS = 6.25 kHz. SCs have a significant effect on network performance.

5.2.2.2 One-hop forwarding time Figure 9 shows the comparison of one-hop forwarding time results obtained by considering different fixed message sizes.

A bridge mode can perform a transmission time based on the average message size in NWMNs. The transmission time as a function of the average size of the message and the CS is illustrated in Fig. 9.

While the results presented in Fig. 10 show that the transmission time increases as the CS values increase. That said, increasing the size of the message can also lead to a significant increase in the transmission time.

Bridge mode can improve forwarding time depending on message size and fixing CS.

5.2.3 Wireless router/bridge mode measurements

Figure 11 shows the results of modulation rates versus CSs for linear and exponential modulation.

The modulation rates of modulation formats QAM [Linear (QAM): 16DEQAM, D8PSK, π/4DQPSK, DPSK] and FSK

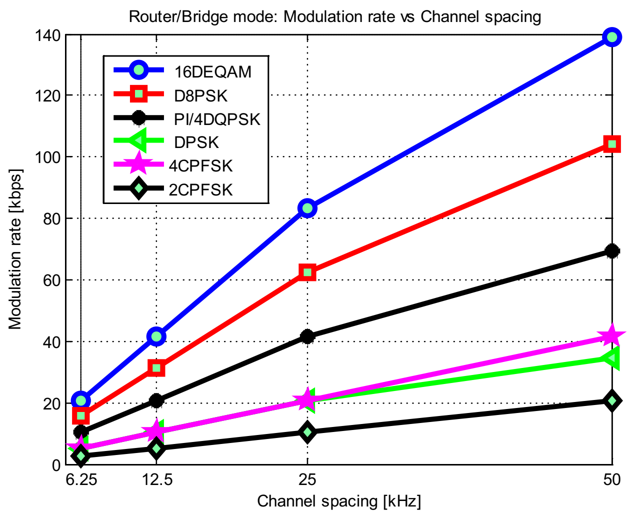

Fig. 11 Modulation rates versus CS for different modulation formats

Table 2 Comparison experimentally measured

	Router mode		Bridge mode	
Message size	500	1500	500	1500
Spacing channel (kHz)	6.25	50	6.5	50
Forwarding time (ms)	258	100	230	94
Payload bitrate (kbps)	16.35	122.45	18.35	130.23
16DEQAM (kbps)	20.83	138.89	20.83	138.89
4CPFSK (kbps)	5.21	41.67	5.21	41.67

[Exponential (FM): 4CPFSK, 2CPFSK] increase considerably with CS. It was also pointed out that the use of higher modulation rates can significantly increase data speeds, but they also result in reducing coverage range including a low receiver sensitivity.

5.2.4 Comparaison (router mode vs bridge mode)

For two packet sizes (500 b and 1500 b) and two CSs (6.25 kHz and 50 kHz), the comparison between router and bridge experimental measurements are summarized in Table 2.

Comparison results demonstrate that in router or bridge modes when increasing message size and CS, the forwarding time and the modulation rate increase while payload bitrate decreases. In the router or bridge mode, message size does not influence the modulation rate. It is the CS that causes an increase. In this case, the forwarding time increases by 38.76% (router mode) and 40.86% (bridge mode) while the payload bit rate decreases 13.35% (router mode) and 14.10% (bridge mode).

Finally, it should be noted that the comparison of measurement and simulation results using a router or bridge mode gives almost the same conclusion.

5.2.5 Comparison with other methods

The authors, in this paper, design a new practical measurement method for measuring Narrowband wireless mesh networks (NWMN) application performance. The authors analyze the effect of message size and channel spacing on the resulting bitrates, forwarding time, and modulation rate through experimental results. In the simulation, a single one-hop packet is transmitted to exploit a versatile radio modem with very-high-frequency radios operating in the bridging or the routing modes. However, the measurement method should be compared with other conventional methods. The performance methods described in [1, 3, 17, 22] have a limited objective using a simple metric that does not give great liberty to choose network performance easily. Also, their evaluation results do not offer global and advanced visibility that not allows the network examiner to quickly identify the services and processes, and it can cause network connectivity issues. But the practical method described in this paper quickly generalize the analysis of Narrowband wireless mesh networks application performance using the robust design metric using only one-hop forwarding time, payload bitrate, message size, modulation, ACK, channel spacing, and maximum transmission unit (MTU), as evaluation parameters.

Moreover, this method includes a comparison with the bridge mode that is absent in the other methods relative to the proposal. The present and the proposed method offers a solution to the problems that are too often required. The method includes both the application for critical services and real-time network monitoring functionality.

The experimental parameters can be correlated with advanced application performance metrics to deliver insights about how to judge the network performance, including the problems that affect the end-user experience. The paper is described the basic concepts utilized in an experimental testbed and their respective results in practice.

6 Conclusions

This paper illustrated the focusing effect of the various packet sizes, CSs, and modulation rates over a wireless mesh network. Experimental results proved the efficacy of the proposed method for a quick performance overview, based on several basic parameters, providing a quick and easy idea of the possible bitrate and forwarding time for the operating mode of the router and bridge network performance. Based on the proposed method, we can see the effect of packet length, spacing channel, and modulation rate on the resulting time or transmission time. Larger payloads improve protocol efficiency, leading to a higher throughput. Measurements of key parameters presented in this paper provide a quick performance overview of specific objectives or application processes, thus enabling faster and prudent decision-making. Even in multiple instances, mesh networks can carry polling or exception reporting applications. The model's router/bridge mode based on the mentioned parameters provides an effective method to estimate network performance under QoS constraint. In practical applications, the correct choice of these parameters brings more benefits. This investigation framework plays an essential role in several issues. Thus, we are now examining the effectiveness of other novel methods for different wireless networks to facilitate the analysis of their performance.

Compliance with ethical standards

Conflict of interest The authors confirm that there is no conflict of interest.

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