Multi path Multi SPEED Contention Window Adapter

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Summary
In this paper, we are interested to enhance the QoS in sensor networks. First, we study the MMSPEED routing protocol (Multi path Multi SPEED) [1] conceived to ensure the quality of real-time services in sensor networks.
We present, then, a second approach which takes advantage of the standard 802.11e EDCA protocol [16] that ensures effective end to end delay and good quality of traffic.
Finally, we tried to improve the provision of quality of service in sensor networks by offering a new approach which aims to improve the mechanism of service differentiation implemented in the 802.11e.

Key words:
Sensor Networks, QoS based routing protocols, MMSPEED, EDCA, Contention Window Adapter.

1. Introduction

Wireless Sensor networks (WSN) are expected to play an essential role in the upcoming age of pervasive computing. In fact, a sensor node is a physical component, able to accomplish three tasks: the record of a physical quantity of the information, the possible treatment of this information, and the communication with other sensors. Thanks to technological progress in the field of the sensor networks and wireless applications, the need to observe, monitor and remotely retrieving data from a complex and distributed environment is growing rapidly. In such networks, sensors exchange information on the environment in order to establish a global view of the region monitored. This information is then delivered to the user through the external gateway node "Sink node". Several challenges need to be reviewed for the provision of real-time traffics: like minimizing the number of packets that miss their deadline in high density networks and taking into account the constraints of sensor networks.
QoS requirements in WSN may be very different from the wired networks. For example, traditional end-to-end QoS parameters may not be sufficient to describe them. As a result, new parameters are used to measure the QoS performance in WSN.

The existing researches related to the QoS in WSN can be classified in three categories [15]: traditional end-to-end QoS, reliability assurance, and application-specific QoS.

We present in the next station the state of the art of the routing protocols based on QoS in WSN. In section 3, we describe the protocol MMSPEED [1] which is an extension of the protocol SPEED.

2. Routing protocols based on QoS in WSN

In WSN, many works have studied routing protocols based on QoS in wireless sensor network.

SAR (Sequential Assignment Routing) [19] is the first protocol in WSN that includes the QoS mechanism. In fact, it is a multi-path protocol that strives to achieve energy efficiency and fault tolerance. SAR creates trees taking into account the QoS metric, the energy resource on each path and the priority level of each packet. In using these trees, paths from sink to multiple sensors are established. One or more routes can then be used.

A QoS routing protocol (SPEED) that provides soft real time end-to-end guarantee is discussed in [9].

This protocol provides routing decisions based on the node position. It differs from other routing protocols because it provides a flexible real-time service. The protocol SPEED requires that each node maintains information about its neighbours. It proceeds by geographic routing to select the next nodes to reach the final destination Sink. In addition, SPEED provides a packet delivery speed noted Setspeed. This ensures an acceptable time. These delays can be estimated by dividing the distance between the source and the sink nodes by the sink speed Setspeed.

In case of path congestion, packet feedback "back pressure" mechanism implemented in each node should warn the downstream nodes to choose a different path [9].

Authors in [4] present QBRP, a routing protocol based on QoS, which meets, simultaneously, the application requirements for low latency, high delivery reliability, uniform energy consumption and fault tolerance. It takes advantage of the interactions among sensors to provide a better QoS solution for WSN.
In [8] some information is used: such as the size and transfer period of data to select one of multi-paths depending on the service differentiation. In addition to an existing path, the proposed algorithm dynamically selects

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an alternative path according to multi-path environments. Moreover, it assigns the shortest path to the traffic with the most strict time restriction.

In real-time routing protocol FT-SPEED [14], void announces scheme is proposed to prevent the packets reaching the void. To route the packets around two sides of the void to guarantee the packets be delivered rather than just being dropped, the void bypass scheme is introduced in FT-SPEED [14].

We present in the next station the protocol MMSPEED which is an extension of the protocol SPEED.

3. MMSPEED

MMSPEED (Multi path Multi SPEED) [1] is an extension of the SPEED protocol. MMSPEED is characterized by offering multi-speed transmission and the establishment of more than one path to the destination. Indeed, for each offered speed, a QoS level and an additional path can be set to improve the quality of traffic. MMSPEED protocol allows sending packets with respect to end to end delay parameter required by the applications in order to avoid congestion and reduce the packet loss rate. Thus, MMSPEED differs from SPEED protocol by offering several QoS levels according to the traffic requirements.

To better ensure the quality of real-time service, the protocol MMSPEED requires that the MAC layer supports also the service differentiation.

MMSPEED interoperates with a MAC layer IEEE 802.11e by the means of the EDCF protocol [12] (Enhanced Distributed Coordination Function).

Several studies tried to guarantee the QoS at the MAC layer. Among these are the protocol EDCA which provides few optimizations in the classification and scheduling of packets ready to be transmitted. In the following, we briefly describe some aspects of the EDCA protocol, its ameliorations and the Contention Window Adapter approach (CWA approach) that tries to solve the problem of the EDCA protocol.

4. EDCA Protocol and Enhancement Works

The IEEE 802.11e MAC protocol specifies an enhanced distributed channel access mechanism (EDCA mechanism) with adjustable parameters, providing differentiated access to wireless stations. The EDCA parameters are: CW_{min} and CW_{max} (minimum and maximum contention window), AIFS (arbitration inter frame space), and TXOP (transmit opportunity). The protocol EDCA controls access to the transmission channel and tries to differentiate the data stream. The values of CW_{min} and CW_{max} for each access category in EDCA are static. In low load networks, the choice of small values for the CW is a suitable choice. These backoff values are randomly chosen between [0, CW]. At the beginning of the backoff procedure, CW is initialized to CW_{min}, and it increases when there is a collision.

Recent studies [5] show through various simulations that defaults settings in EDCA protocol are unable to guarantee end to end delay application requirements in the high load networks. In [17] authors study the limits of the EDCA protocol when supporting Real-Time traffic.

The EDCA protocol is discussed in [2] [3] [7] [11] [17] [18] in order to enhance its performance. A modified EDCA protocol with dynamical contention control mechanism (DCC) for real-time traffic in multi-hop ad hoc network is discussed in [2]. A simple adaptation scheme is proposed in [3], where the access point adapts the contention window based on the network conditions.

The main problem of the original EDCA is that the values of the main parameters of each access categories queue (AC) (such as contention window limits) are static and do not take into account wireless channel conditions. The authors in [7] present an approach to split the contention windows per AC into different sub-windows. This method decreases channel collisions and maintains low delay and high throughput.

In [11] authors present a Contention Adaptation (CA) mechanism to improve the energy efficiency in IEEE 802.11e EDCA. By suspending some transmissions, the proposed protocol can reduce the number of collisions. Because unnecessary retransmissions are eliminated, the energy consumption is also reduced.

EDCA implements no mechanism to change the size of the contention window between various categories of access depending on the network.

The approach proposed in [18], which is used in our work, consists to dynamically change the size of the contention window between various access categories in the context of overloaded networks. In the following section, we present the MMSPEED Contention Window Adapter Protocol.

5. MMSPEED Contention Window Adapter Protocol: MMSPEED_CWA

The Contention Window Adapter (CWA) mechanism tries to reduce the number of collisions. Some approaches like in [18] adapt dynamically the range of CW_{min} and CW_{max} in each access category. It uses a parameter which is the ratio between the number of collisions affecting high-priority packets and the total number of packets sent in this category during a time interval. This parameter represents the collision level.

If the rate is below the threshold A, this indicates that the network is low. In order to accelerate the backoff process, it is preferable to reduce to half the values of CW_{min} and CW_{max} of different access categories ($CW_{max}[i]=CW_{maxold}[i]/2$;$CW_{min}[i]=CW_{minold}[i]/2$).

If the rate is between two values A and B (such us A <B),

then the values of CW_{min} and CW_{max} are maintained ($CW_{max}[i]=CW_{maxold}[i]$; $CW_{min}[i]=CW_{minold}[i]$). If the rate is between B and C (such us B <C), then the network load is high. Thus, to reduce the number of collisions, the CWA mechanism increases CW_{min} and CW_{max} values of different access categories by doubling their current values($CW_{max}[i]=CW_{maxold}[i]*2$;$CW_{min}[i] = CW_{minold}[i]*2$). If the rate exceeds the maximum threshold C, then the network is very congested. Therefore, CWA mechanism doubles twice the values of CW_{min} and CW_{max} ($CW_{max}[i]=CW_{maxold}[i]*4$;$CW_{min}[i]=CW_{minold}[i]*4$).
Table1 shows CWmin and CWmax combinations. At instant t, if the current combination is the one displayed on the second row, and at time $t+ \Delta t$ the collision level is between A and B , then the CW_{min} and CW_{max} values of the various ACs will be maintained.
If the collision level is below A then CW_{min} and CW_{max} values of the various ACs will be set as in the first row.

Table1. CWmin and CWmax combinations

	CWmin (VO)	CWmax (VO)	CWmin (VI)	CWmax (VI)	CWmin (BE)	CWmax (BE)	CWmin (BK)	CWmax (BK)
1	7	15	15	31	31	1023	31	1023
2	15	31	31	63	63	1023	63	1023
3	31	63	63	127	127	1023	127	1023
4	31	63	127	255	255	1023	255	1023
5	31	63	255	511	511	1023	511	1023

To implement the MMSPEED_CWA protocol, we don't change the network layer (i.e. we keep intact the protocol MMSPEED in this layer), but we change the MAC layer by introducing the EDCA protocol, which leads to the MMSPEED_EDCA protocol. Then, we change the classical Contention Window mechanism implemented in EDCA protocol by the CWA mechanism, which leads to our new protocol named MMSPEED_CWA.

6. Simulation results

We have implemented and simulated MMSPEED, MMSPEED_EDCA and MMSPEED_CWA protocols. We compare the performance of these protocols in terms of end to end delay and quality of traffic metrics. Simulations are made by using JSIM simulator (Java Simulator) [13].

Table 2. Simulation parameters

Number of nodes	50
Space size	200 m* 200 m
Radio range	40 m
Packet size	32 octets
Bandwidth	200 Kbps

EDCF MAC Parameters

Priority classes	2
SIFS	10μs
TimeSlot	20μs
Persistent Factor(PF)	2
Higher Priority traffic	***Lower Priority traffic***
AIFS[0]=2	AIFS[1]=5
$CW_{min}[0]=15$; $CW_{max}[0]=255$	$CW_{min}[1]=127$; $CW_{max}[1]=1023$

EDCA MAC Parameters

Priority classes	2
SIFS	10 μs
TimeSlot	20 μs
Higher priority traffic	***Lower priority traffic***
AIFS=2	AIFS=7
$CW_{min}[0]=7$, $CW_{max}[0]=15$	$CW_{min}[1]=31$, $CW_{max}[1]= 1023$
PF =1	PF=2

Table 2 shows the simulation parameters we use. In fact, we place the nodes randomly in the network, while the SINK node is located at the origin at coordinates (0,0,0).
We compare, in the first time, MMSPEED_EDCA and MMSPEED according to the end to end delay constraint. Then, a second comparison is made on the constraint of quality of traffic and end to end delay. The combination of these two constraints is very useful for the interpretation of the behaviour of each protocol. In the second step, we measure the performance of the MMSPEED_EDCA protocol in high load network. Then, we evaluate and compare the MMSPEED_EDCA protocol versus MMSPEED_CWA protocol in term of QoS during the transmission of real time traffics.

6.1. MMSPEED versus MMSPEED_EDCA

6.1.1. End-to-end delay

We compare the performance of the two protocols MMSPEED and MMSPEED_EDCA in term of end to end delay metric. We use the same rate of DPDR: Desired Packet Delivery Ratio which is equal to 50% for all streams. However, we divide the flow in two groups: The first type of traffic is high priority traffic, it has strict end-to-end delay requirement: 0.3 sec. The second type of traffic is low priority traffic, it has a deadline of 1 sec. In our context of simulation, the network layer is composed in two virtual layers. The first layer provides a significant delivery speed: 1000 m / s, to meet the strict requirements of traffic. The second virtual layer transmits packets in a low speed equal to 250m/s.

Figure 1 shows that for both protocols, the average end to end delay increases with the increase of the source nodes.

The two protocols MMSPEED and MMSPEED_EDCA have a peak of 0.85 seconds between the traffic of higher priority over the traffic of lower priority. This can be explained by the fact that these two protocols offer transmission speeds in accordance with their priorities for each jump. Up to 5 sources, the different protocols behave the same way regardless of type of traffic. From 10 sources, we find that the two protocols with the lowest priority traffic degrade significantly the end to end delay.

While they are stable for the priority traffic: the end to end delay never exceeds 0.3s even at high load.
This experience has demonstrated the contribution of the protocol EDCA against the protocol EDCF in guaranteeing the QoS time. This is justified by the fact that the protocol EDCA provides few optimizations in the classification and scheduling packet ready to be transmitted.

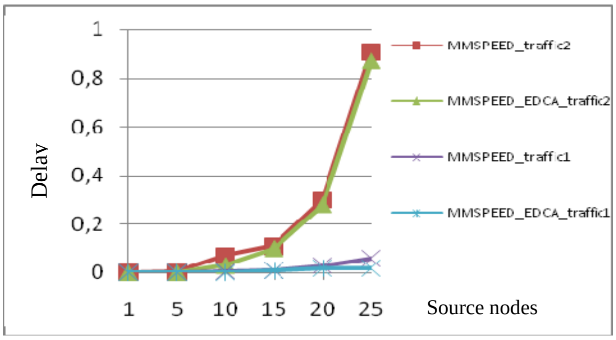

Fig 1. Average end to end delay

6.1.2. Combined constraints: end to end delay and traffic quality

To study the performance of the protocols MMSPEED and MMSPEED_EDCA according to the two constraints end to end delay and quality of traffic, we carried out an experiment which classifies the data stream into four categories:

- Traffic1: with large end to end delay equal to 1s and high quality traffic equal to 0.7.
- Traffic2: with short end to end delay equal to 0.3s and high quality of traffic equal to 0.7.
- Traffic3: with large end to end delay equal to 1s and low quality of traffic equal to 0.2.
- Traffic4: with short end to end delay of 0.3s and low quality of traffic equal to 0.2.

Figure2 shows the PDR generated by the MMSPEED protocol of which end to end delay have not exceeded the time limit for the different types of traffic. This rate decreases gradually when increasing the number of sources. In spite of the decrease, each class of traffic keeps a PDR above the threshold and verifies the quality of traffic required. This shows the reliability of the MMSPEED protocol that guarantees the QoS in terms of end to end delay and quality of traffic.
Figure3 represents the improvements of the MSPEED_EDCA protocol compared to MMSPEED protocol in term of the quality of traffic.

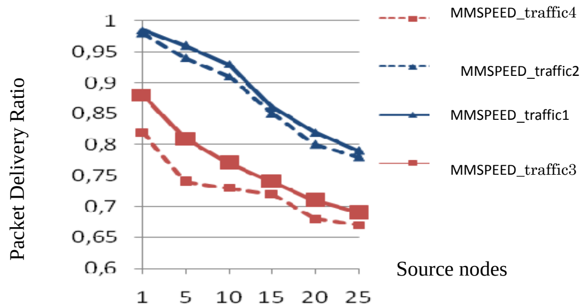

Fig 2. PDR: MMSPEED

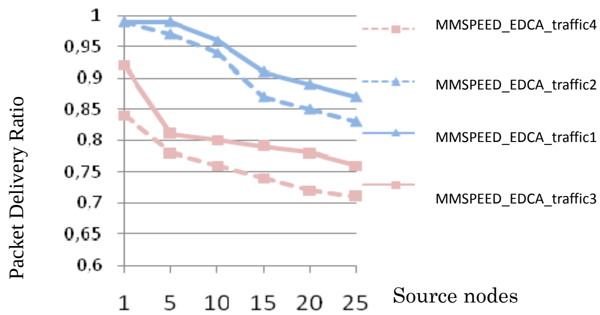

Fig 3. PDR: MMSPEED_EDCA

6.2.MMSPEED_EDCA versus MMSPEED_CWA

To evaluate the performance of the protocol MMSPEED_CWA based on the mechanism of adjustment of minimum and maximum contention window, we choose the following parameters A, B and C: A = 0.1, B = 0 .2 and C = 0.3.

6.2.1. End-to-end delay

The coupling of the two protocols MMSPEED (belonging to layer network) and EDCA (belonging to layer MAC), has improved the real-time traffic performance in the sensor networks. However, if we consider a high load network, the MMSPEED_EDCA protocol is unable to meet end to end delay requirements. We simulate two traffics requiring similar DPDR (Desired Packet Delivery Ratio) equal to 50%. The first traffic requires a short deadline of 0.3 second and the second traffic require a long deadline of 1 second. However, in this experiment, we are interested in assessing the performance of the higher priority traffic.

Thus, we distinguish two types of traffic priority:

- Traffic1: with end to end delay of 0.3, quality of traffic of 50% and emission speed of 10 packets / s.
- Traffic2: with end to end delay of 0.3, quality of traffic of 50% and emission speed of 30 packets / s.

It is clear that the performance of the MMSPEED_EDCA protocol is the worse when increasing the network load. As shown in Figure 3, the protocol MMSPEED_EDCA can not meet the deadline required for traffic1 when source number is greater than 42. The same thing happens for traffic2 when source number is greater than 35. Our protocol (MMSPEED_CWA) is better for both traffics. It optimizes the delivery time for trafic1 with a margin of 0.08 seconds in a network of 45 source nodes. This can be justified by the new mechanism implemented in MMSPEED for adjusting dynamically the range of the minimum and maximum contention window.

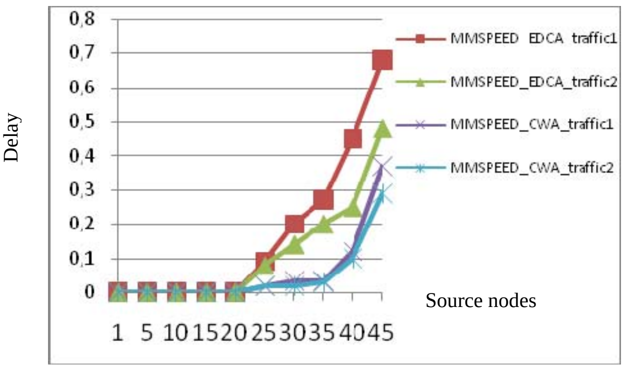

Fig.4 Average end to end delay: MMSPEED_EDCA and MMSPEED_CWA

This experience shows the contribution of CWA mechanism in enhancing the end to end delay metric in real time traffic.

6.2.2. Packet Delivery Ratio

To justify the performance of the MMSPEED_CWA protocol in term of PDR, we take the same scenarios described above, with the constraint DPDR = 70% for traffic1 and DPDR = 20% for traffic2. We distinguish two types of traffic:

- Traffic1: with a quality of traffic of 70% and emission speed of 10 packets / s.
- Traffic2: with a quality of traffic of 70% and emission speed equal to 30 packets / s.

Figure 5 shows that the PDR decreases gradually with increasing the network load. In fact, the available PDR for traffic1 which requires emission speed of 10 packets / s is increased about 10% compared to that achieved by the protocol MMSPEED_EDCA. Similarly, the MMSPEED_EDCA protocol shows good performance even in high load network.

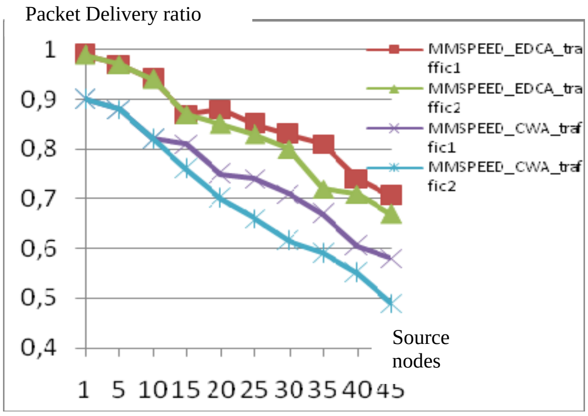

Fig.5 Packet Delivery Ratio: MMSPEED_EDCA and MMSPEED_CWA.

7. CONCLUSION

To meet the requirements of real-time applications encountered in wireless sensor networks, it is necessary to develop new mechanisms to provide better real-time QoS in WSN. We have implemented a new protocol named MMSPEED_CWA based on MMSPEED (Multi path Multi SPEED) protocol developed by E.Felemban, C.Lee, and E.Ekici. In our new protocol, we have changed the classical contention window mechanism implemented in EDCA protocol by the contention window adapter mechanism. We have implemented and simulated MMSPEED, MMSPEED_EDCA and MMSPEED_CWA protocols by using JSIM simulator. Results show that the MMSPEED_EDCA protocol presents the better performance even in high load network. Indeed, the CWA mechanism enhances both: the packet delivery ratio and the end to end delay metrics in real time traffic. In perspective, we will try to optimize the energy consumption in the MMSPEED_CWA protocol.

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