Quality of Service Based Error Handling Scheme for Streaming Applications in Wireless Sensor Networks

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In wireless sensor network a Quality of Service (QoS) guarantee is essential for successful delivery of multimedia over network traffic. Challenges in media streaming WSN include high bandwidth on demand, consumption of high energy, quality of service provisioning, data processing/compressing techniques and cross layer design. This paper proposes an adaptive QoS based error handling scheme called QUES, to support in error handling for each variable service sessions based on policy-control rules in order to control transmission errors for different applications such as streaming content delivery over WSN networks using route metrics. A real time test bed approach along with a case study is adopted to test the data error during transmission along with its effective delay and latency.

Key words: QoS, WSN, BER, Delay, QUES, Error handling.

A Wireless sensor networks consist of multiple sensor nodes. Those nodes are densely deployed in an unattended environment. The sensor nodes are deployed in a self organizing environment by establishing radio communication paths from various sources to a sink[1]. The sensing devices normally low power devices possessing a microcontroller for information processing, a microchip and an antenna for radio communication, and a sensor for sensing environmental parameters such as temperature, humidity, light intensity and more. It comprises the capabilities of sensing, wireless communications and data computations. It also incorporated collecting data, disseminating of environmental data and processing data.

The major applications of WSN related to environment aware services are as follows

1. Defense and Military applications such as target tracking; there are multiple tiny sensors that are being deployed in a geographical terrain to track the movement of enemy vehicles.
2. Habitat monitoring and environment aware applications: There sensor nodes are deployed in remote forests or jungles. These sensors monitor the habitat behaviour of animals or birds.
3. Environmental Safety applications: These includes fire or smoke detections, where the sensors detect smoke in a building[4,5]. It also helps in tracking the fire source and the direction in which the fire expands in a building. It assists especially in rescue and recovery during critical situation.

Even though there are numerous research works which model the networking performance based on behaviour of WSNs[3], the practical implementation and evaluation of networking in real test-bed environments are limited. The large variations of the wireless networking environment

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and simplified hypotheses, lead to major challenges in modeling the setup, which as well attributes importance to the implementation of system is required.

Error handling and QoS in WSN

Several research works have addressed the MAC aware error handling approach and QoS issues of routing in WSNs. Research works [15,16] focusing on QoS analysis on energy consumption and error tradeoffs between the data loss and retransmission in WSN over (CSMA/CA) MAC protocol supports the view that energy consumption function does not consider the power consumption in idle mode. These led to the algorithm that might not get the real error efficient data aggregation tree. In addition to that, the retransmission latency is not considered, so that it does not guarantee the delay QoS. The phenomenon of error handling is always linked to QoS issues; the QoS support in WSN has been much discussed by researchers[6]. On the other hand, a lesser amount of attention has been paid to mechanisms to deliver end-to-end QoS and support in multi-hop WSN environments. Actually, it is a systematic work under a given QoS frame work, QoS control and support need to be implemented at several sub-layers, which involves the following research aspects:

i) QoS framework, overall system architecture to support QoS.

ii) QoS routing algorithm, that focuses on routing layer issues such as how to deal with route computation and maintenance that satisfy both QoS and routing constraints.

iii) QoS signaling for reserve and release network resources.

iv) QoS MAC algorithm, with media access mechanism support for QoS control.

According to network structure, the routing protocols for WSN are classified as flat, hierarchical, and location-based protocols. Also, these protocols are classified into query-based, multipath-based, negotiation-based Quality of Service based, or coherent based depending on the protocol operation. Moreover, these protocols are classified into three categories, viz reactive, proactive, and hybrid protocols depending upon route discovery. Routing in WSNs is a challenge due to the inherent characteristics that distinguish these networks from other wireless networks like mobile ad hoc networks or cellular networks[7], where few important aspects are listed below:

i) Node deployment is application-dependent and is either manual (deterministic) or randomized.

ii) Position awareness of sensor nodes is vital, since data collection is normally based on the location.

iii) Energy consumption without losing accuracy. Sensor nodes are tightly constrained in terms of energy, processing, and storage capacities, so they require careful resource management.

Literature Survey

Jong-Suk Ahn et.al (2005) developed an algorithm that adjusts the FEC code size based on the channel status indicated by the arrival of acknowledgement packets[2]. It rises to the higher level FEC at a packet loss otherwise descending to the lower level FEC in a Multiplicative Increase Additive Decrease (MIAD) way. The existing algorithm works with Type I or Type II, which determines the strength of FEC code or the amount of FEC code that is sent in next transmission. Saad B. Qaisar and Hayder Radh (2007) proposed OPERA-An Optimal Progressive Error Recovery Algorithm for Wireless Sensor Networks. This method presents a novel framework for processing within the network (in-network)[11]. For channel coding it uses, irregular Low Density Parity Check (LDPC) codes, the information at intermediate nodes are progressively decoded by nodes. Wessam Ajib et.al.(2007) proposed MIMO link layer transmission techniques based on cross layer design. This method propose and evaluate the performance of new link layer frame transmission techniques for MIMO (Multiple Input Multiple Output) wireless systems from a link layer perspective using Frame Error Rate (FER), Frame Loss Rate (FLR) and link layer throughput metrics[12]. Raghu K. Ganti et.al. (2006) proposed that the data link layer framing in wireless sensor networks usually faces a trade-off between large frame sizes for high channel bandwidth utilization and small frame sizes for effective error recovery. Having given that the high error rates of inter mote communications, Tiny OS opts in favor of small frame sizes at the cost of extremely low channel bandwidth utilization[10,13].

Bhunia (2011) proposed Packet reversed packet combining technique. Most of the error correction techniques tackle single bit error. When bit error rate is 10^{-2} or less, the double bit error or higher error is insignificant compared to that of single bit error[9]. They implemented eight different Error Correction Codes (ECCs), ranging from simple bit-repetition schemes over Hamming codes to complex Bose-Chaudhuri-Hocquenghem (BCH) codes and three run-time adaptive FEC schemes which adapt the correctional power of ECCs to the current link quality.Brice Barotin et.al. (2012) proposed routing protocols using probabilities and geo location for communications in Wireless Sensor Networks. The aim is to improve the routing protocols in wireless sensor networks by adding tolerance for the errors of nodes' geo location, hence it helps a node which can select the next node in the path to send a message and save energy[8].

QUES model and framework

Fig 1 shows the QUES modeling framework that adopts Markov deterministic framework architecture to predict the behaviour of network. Markov Deterministic Modeling Approach [MDMA] frame work works on function of MDP is to determine the optimal policy that will satisfy the current QoS of streaming media applications. The Markovian property states that the occurrence of a future state in a Markov process depends on the immediately preceding state and only on it but does not depend on the past states. MDP helps in determining the optimal QoS for varying networks and applications.

Hence based on the varying QoS parameters of WSN, optimal QoS service is provided to media applications. A single server queuing system with a finite buffer and heterogeneous arrival streams has been considered. The arrival process is a Poisson or Markov Modulated Poisson Process (MMPP) while service times are with general distributions. In this classical problem of queuing theory, the probability of buffer over flow and packet dropping probability are computed. It also considers multiple transmission rates depending upon the channel conditions, distance and transmitting power. Each mobile station transmits data at an appropriate transmission rate using a particular modulation scheme based on the perceived signal to noise ratio. The service provisioning is dynamically varied by selecting links that can use higher bandwidth modulation schemes. The main focus of this paper is integrated wireless channel modeling and data queuing analysis at the packet level to study the effect of physical layer link speed on high layer network performance. Assured forwarding (AF) in DiffServ is used to provide differentiation service between traffic classes where the low priority class experiences higher loss rates and delays than the high priority class. Arrivals are modeled as a general batch Markov arrival process in which thresholds and packet dropping probabilities are selected so that real time and non real time traffic observe different QoS performance while considering the impact of varying the physical layer link speed in a realistic WSN environment.

QUES Algorithm

QUES algorithm works based on three functions. Three major functions are carried out by any generic routing protocol – discovery of new route, selecting an optimal route among the several available routes, and perform route maintenance and update for data transfer. Same functionalities are also incorporated in QUES by implementing features like route request, route reply, and reporting route errors.

Fig-2 shows the message flow of QUES which indicates the simplified execution flow of the algorithms. The QUES_SREQ and QUES_SRLY packet contains three more fields to accommodate QoS parameters such as bandwidth, delay and packet loss, in addition to the required fields for transferring data.

A source node initiates a route discovery to the destination by sending QUES_SREQ packets towards its neighbours. As soon as the QUES_SREQ packets are received, the neighbour or the destination will process those QUES_SREQ packets. If the neighbour can satisfy the QoS requirements, it will forward the QUES_SREQ packet to the next neighbour or destination. If the destination node has received the QUES_SREQ, then it will send a QUES_SRLY packet to the source.

When a node receive a QUES_SRLY packet, if it still has the required resources available, it creates a forward route entry to the destination, reserves the required resources and then forwards the QUES_SRLY packet to the upstream nodes using the reverse route.

When the source receives the QUES_SRLY packet from the destination, it will create a route to the destination in the routing table. Subsequently, the data transmission to the destination is initiated by the source. On the other hand, a node that receives a QUES_SRLY packet, and does not have enough resources to satisfy the data transfer, it drops the QUES_SRLY packet, generates a QUES_ERR packet, and sends it back to the node from where it received the QUES_SRLY packet.

Experimental Test bed

The parameters involved for simulation are lifetime, number of active nodes for communication, percentage of packet loss and delay. MATLAB software has been used for analysis purposes and evaluating node and route efficiency. The network test bed consists of random topology having desirable nodes with dynamic topology.. Figure 3 shows the MAMA board setup that is used to test the QUES algorithm.

Multiple MamaBoard kits were used for carrying out real time testbed. MamaBoard combines a Tiny Node Standard Extension Board (SED) and a cellular GPRS module on a single device. The MamaBoard is intended to bridge a wireless sensor network to wireless LAN (WLAN)[14] or GPRS. Each connectivity type is enabled by plugging an appropriate external module to the MamaBoard. The SD (secure digital)slot can be accessed both by the TinyNode and the GPRS module. The Siemens TC65 is the GPRS module which can be mounted on Mamaboard. This kit includes a simplified version of J2ME (Java 2 Mobile Environment). Hence, Java applications can be executed on the GPRS module. The TC65 comes with an integrated TCP/IP stack which allows establishing, standard Java socket connections to a server by using AT commands. The TC65 is connected to the MamaBoard through a 80 pin board-to-board connector.

The primary aim of this work is to ascertain the fixed value for aggregate background traffic and to continue with experimental test bed with the chosen value of 2.3 Mbits. This setup is maintained throughout the test run, as similar to tests to be conducted for bandwidth-constrained applications as well to maintain the delay bounded setting with different values. In the experimental test bed, the network setup values vary between 10 and 100 ms. On analysis from the test bed results it can be observed that applying a maximum delay threshold of 20 ms for no video or voice traffic was accepted as cut-off value into the network.

Fig 4 shows the nodes in mobility. There are ‘N’ sensor nodes are located randomly within a square border of 10*10 m^2, where N is fixed as 20. The initial communication range of nodes is considered as 0.1cm. The connective range of nodes is 50 to 60 meters, which considers that each 2 nodes being located at a distance of less than 60 m are considered as neighbours hence can exchange data. Events are sensed periodically such that for each period an event occurrence is observed. Value

Table 1. Property used in Test-bed

Area of Test bed	10 x 10m^2
N	20
Initial energy	0.01s
frequency	700khz
Connective range	60m
Sensing range	30m
Sink	300, 300

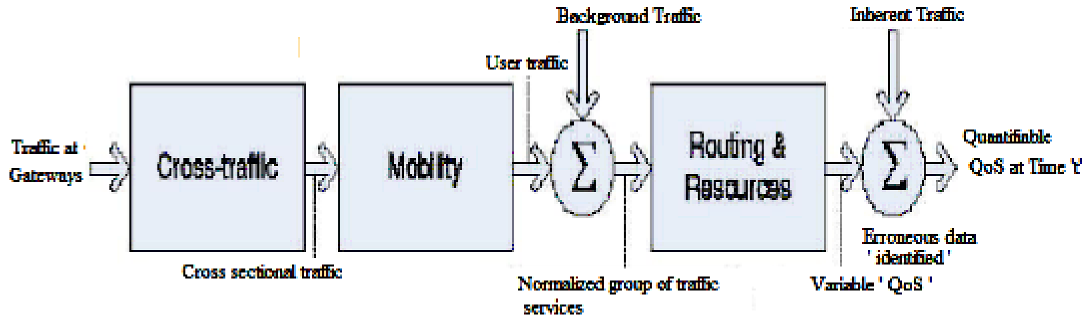

Fig. 1. Traffic controller architecture for QoS

of route selection for update of selection probability of a node is taken 0.001s.

Table-1 shows the testbed properties. To understand and evaluate the average behavior of the protocol, QUES protocol variant had been implemented in the test-bed framework. According to the test bed requirements, which focus adopting a simple star topology, 20 nodes are deployed in the field. All the nodes are randomly distributed with consistent mobility.

Performance Analysis

The test run was performed for 5 iteration runs where each individual experiment. The graph (fig-5), shows a error rate observed as curve between the mean interval time for QUES algorithm, which happens at packet interval of about 0.01 s. The curve relates to maximum channel utilization. This observation shows that the channel clearly provides capacities that can be used for real-time traffic and non real time traffic.

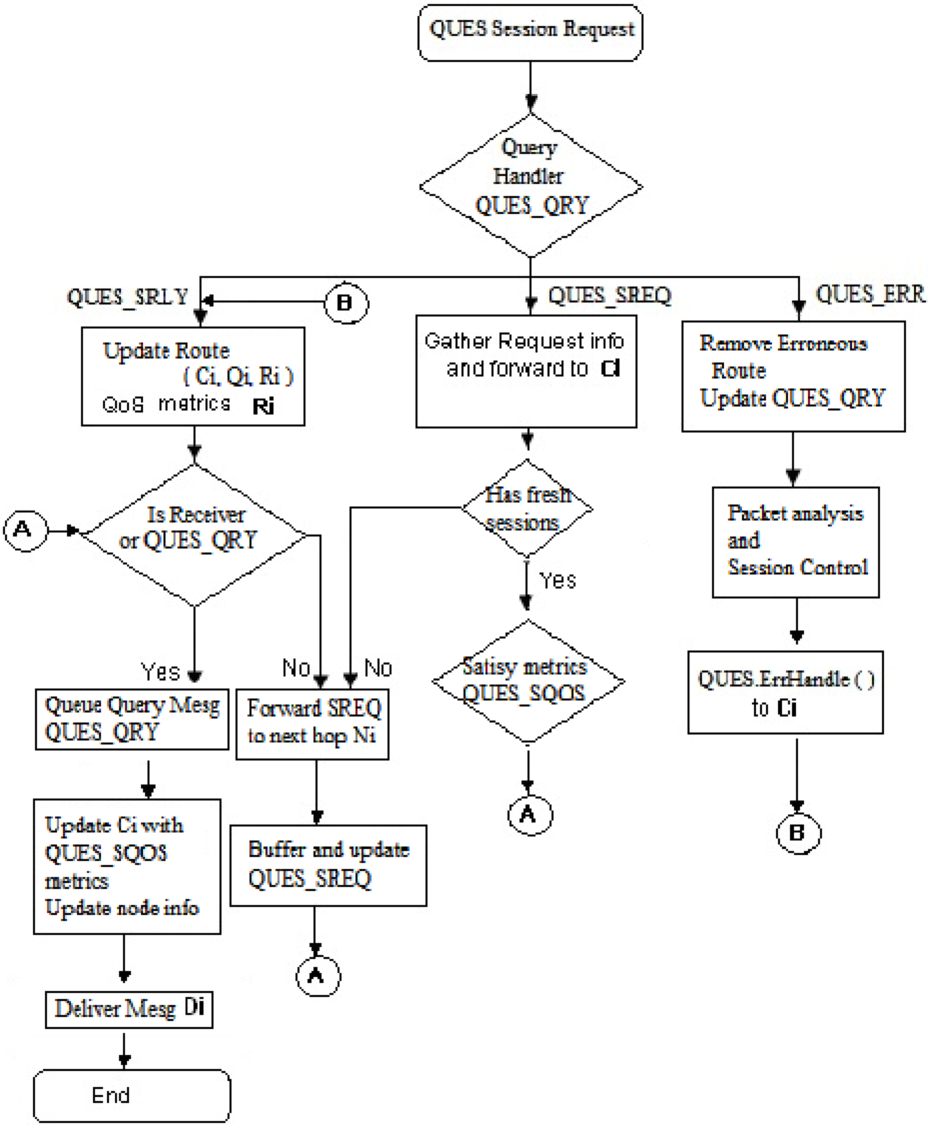

Fig. 2. QUES Flow chart

This work extends the performance evaluation of study and analysis of the protocol behavior using selected real time experimental run time functionality. The analysis of real-time capabilities of both the standard protocol ARQ scheme with FEC and QUES (proposed protocol variant) is carried out as part of this research work. Analysis also investigates the packet loss rate and the possible throughput depending on the traffic load. The results being depicted in Fig-5, Fig-6 and Fig-7 using relative experiments confirms the analytical evaluation of network traffic. Depending on the traffic load, the optimal situations of delay bounds are controlled such that no packet loss occurs. However, at a defined throughput threshold of about 0.01s for the packet interval, the channel becomes densely saturated and delay increases based on buffering effects.

Fig. 3. Mamaboard setup for testing QUES

Fig 5 shows the Bit Error Rate analyzed over Mean Frame Interval Time (calculated during $15x10^3$ ms time slots) which is referred through the inferred network model and test-bed approach. Fig 6 represents the total bandwidth consumed. It is observed that the impact of imposing delay

Fig. 4. TinyNode testing for QUES on mobility

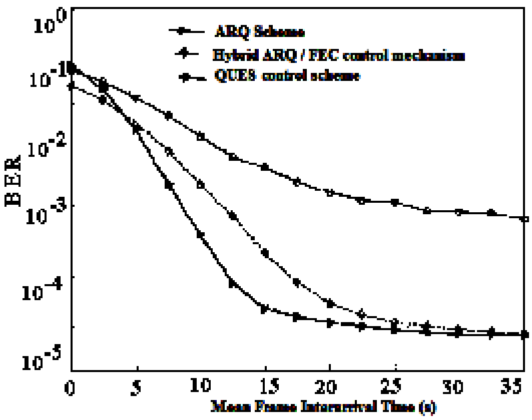

Fig. 5. Bit Error Rate analysed over Mean Frame Interval Time

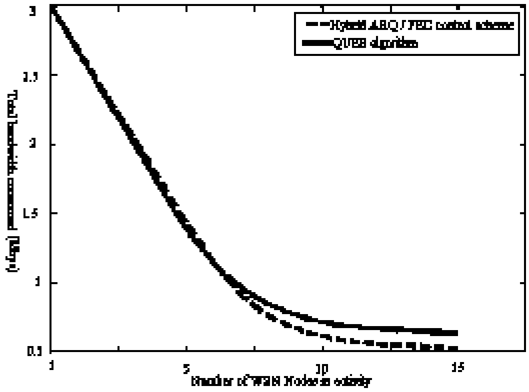

Fig .6. Bandwidth utilization corresponding to number of active WSN nodes requirements is more pronounced on video sources, being that the voice traffic only varies slightly by 12% as expected.

Fig.7 shows the comparison between the average variance of combined TCP delay by observing the number of nodes in activity. From the obtained results, it can be concluded that the QUES model was able to predict adaptiveness as well provide QoS, with a high precision level behaviour in simulation test cases. This result is expected since the model was constructed using the first 60 minutes of data from the scenario of varying number of users.

This work can be summarized as the model was able to predict network behaviour even when the number of users increased by a factor of 200%. Based on the obtained results, it is observed that even for large increments in the number of users and network traffic the model was still able to produce very accurate predictions. This work proposed a novel approach to modeling of WSN networks, which is based only on measurements (or simulations). Initially QUES model work on set of simulated measurements of the inbound/ outbound traffic and of the corresponding Quality of Service (QoS). The test bed works on relative set of real time measurements and updates such that finally the system converges to predict the QoS from the inbound/outbound traffic.

The model does not impose any restrictions to the type of metrics that characterize network QoS. The results obtained from applying the presented procedure to realistic network scenarios showed that this approach can achieve excellent performance in terms of predicting QoS

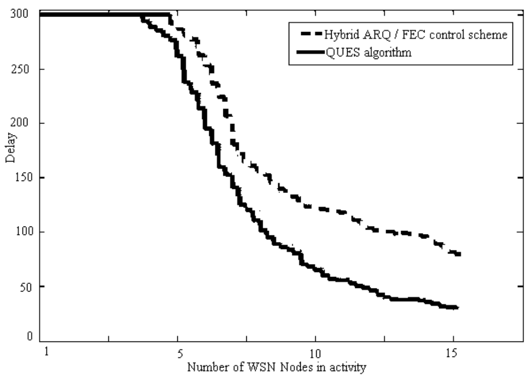

Fig .7. Packet Delay observed for number of WSN nodes in activity

of multiple network access points or gateways. The QoS prediction was accurate even when there were significant changes in the number of users.

CONCLUSION

The multimedia content in sensor networks should be delivered with predefined levels of Quality of Service (QoS) under resource and performance constraints such as bandwidth, energy, and delay. These constraints limit the extent to which the QoS requirements can be guaranteed. This paper discusses on the performance of QoS based approaches for WSN using scenario based test bed approach. It is identified from the result that the QUES algorithm performs better than the conventional Hybrid ARQ/FEC approaches related to the parameters BER, bandwidth and delay. In a real scenario network environment, where timely reception of each packet and session based routing plays crucial role, helps in effective transmission of packets. The study and analysis shows that the proposed QUES algorithm performs better when compared with the conventional approach. In future, the work can be extended by analyzing routing strategies and also can be compared with the existing routing algorithms for different set of multimedia data.

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