Dynamic Slot Allocation for Improving Traffic Performance in Wireless Sensor Network

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Abstract - *Wireless sensor networks have recently received increased attention for a broad array of applications such as surveillance, environment monitoring, medical diagnostics, and industrial control. A wireless sensor network (WSN) contains numerous small sized sensor nodes that have computation power. In WSNs serious incident data collected by the sensor nodes are to be reliably delivered to the sink for successful monitoring of an environment. The battery is the main energy source in the wireless sensor network. For better performance battery power should be sufficient. More energy consumption reduces the lifetime of the wireless sensor network. Also, if the channel utilization is more than throughput of the wireless sensor network reduces. Thus, wireless sensor networks medium access control (MAC) protocols for energy efficiency comes at the cost of extra packet delay and limited throughput, since a sender is allowed to transmit in the short active periods, only. However, typical applications, in addition to low rate periodic traffic, also present burst traffic triggered upon event detections. Therefore, there is an emerging need for a MAC protocol that adapts its offered bandwidth to a dynamic traffic load, i.e., maintain low duty-cycle in light traffic condition and schedule more transmission opportunities when traffic increases so that the energy is only used for carrying the application traffic whenever needed. In this paper we propose a scheme which reduces the traffic in the network using dynamic channel allocation. The duty cycle of the network is also improved.*

Key Words: Wireless Sensor Network, dynamic slot allocation, MAC, CSMA, TDMA, Queue length.

1.INTRODUCTION

A wireless sensor network (WSN) [1] encompasses of several lesser sized sensor nodes that have low working out power. It also have communication ability and sensing functionalities. Wireless sensor networks establish a specific type of wireless data communication networks. Every sensor node can sense physical characteristics. WSNs have been the favorite choice for the succeeding generation monitoring and control systems. It can sense temperature, light, vibration, humidity, electromagnetic strength or any other physical characteristic, and communicate the sensed information [2] to the other node through a series of numerous in-between nodes that assist in forwarding the data. The design challenges of WSN are limited energy capacity, sensor locations [3], random and massive node disposition, inadequate hardware devices, network system features and data aggregation, unreliable environment, scalability, and assorted recognizing application necessities. In WSNs, severe happening data composed by the sensor nodes is to be consistently distributed to the sink for efficacious observing of an environment. The various applications of wireless sensor network are smart grids and energy control systems, industrial applications, transportations and logistics, smart building for example indoor climate control, health care for example medical health diagnostics and health monitoring, precision agriculture, animal tracking, urban terrain tracking and civil structure monitoring, entertainment, security and surveillance.

The communication of WSN is not only effected by antenna angle but also by weather conditions, obstacles etc. Further, it is also depends on interference. Nodes in WSNs are disposed to letdown due to hardware letdown, energy reduction, communication link faults, mischievous attack, and so on.

Nodes in sensor networks have very limited energy. The main WSN objectives are less power consumption, better channel utilization, less node cost, small node size, scalability, security, fault tolerance, adaptability, QoS [4] support and self configurability. Routing rules of wireless sensor network naturally adjust themselves with the current environments which may vary with high mobility to low mobility in extremes along with high bandwidth.

Routing in wireless network is different from simple adhoc network. Wireless sensor network is infrastructure less. Wireless links are not reliable. All the routing protocols of wireless sensor network require good energy. Wireless sensor node may fail because of infrastructure. The wireless sensor network protocols are location based protocols, hierarchical protocols, data centric protocols, multipath based protocols, QoS based protocols, mobility based protocols, and heterogeneity based protocol. A few protocols reported in literature are as follows: Location based - GAF, TBF, SMECH, GeRaF, MECN [5], GEAR, Span, BVGF; Hierarchical Protocols - APTEEN, LEACH, HEED, PEGASIS, TEEN; Data-centric Protocols - Rumor Routing, ACQUIRE, Quorum-Based Information Dissemination, SPIN, EAD, Information-Directed Routing, HABID, GBR, EAR, IDR, COUGAR, DD; Heterogeneity-based Protocols - CHR, CADR, IDSQ; Multipath-based Protocols - Braided Multipath, Sensor-Disjoint Multipath , N-to-1 Multipath Discovery;

Mobility-based Protocols - TTDD, SEAD [6], Dynamic Proxy Tree-Base Data Dissemination, Joint Mobility and Routing, Data MULES; and finally QoS-based protocols - SPEED, Energy-aware routing, SAR.

The battery condition of WSN node is very important factor for better communication. The hardware in good condition is very necessary for WSN communication. To maintain a sensor network running in a normal condition, many applications such as time synchronization, reprogramming, protocol update, etc are necessary in flooding [8] manner. To achieve availability, integrity and reliability routing rules should be robust against malevolent attacks.

In this paper, we propose an algorithm which improves the duty cycle, the network lifetime and reduces energy consumption. The experimental outcomes depict the improvement in the throughput of the system and end to end data transmission, reduction in the traffic of the wireless sensor network due to dynamic channel allocation thereby improving the overall system performance.

The rest of the paper is organized as follows. Section 2 provides a brief literature survey related to wireless sensor network, and the routing protocols used in wireless sensor network. Section 3 concentrates on the proposed work, algorithm of the proposed work. Section 4 provides the implementation and result analysis. Finally, Section 5 provides concluding remarks, limitation discussion.

2. LITERATURE SURVEY

Wireless sensor networks (WSNs) have been widely used in many application areas such as infrastructure protection, environment monitoring and habitat tracing. Because of more energy consumption, the lifetime of the wireless sensor network reduces. Also, if the channel utilization is more than throughput of the wireless sensor network reduces. Thus, wireless sensor networks medium access control (MAC) protocols for energy efficiency comes at the cost of extra packet delay and limited throughput, since a sender is allowed to transmit in the short active periods, only. Hence, to provide high throughput and short delay, while still keeping low power consumption is still a research challenge in current WSNs MAC protocols. However, typical applications, in addition to low rate periodic traffic, also present burst traffic triggered upon event detections. Therefore, there is an emerging need for a MAC protocol that adapts its offered bandwidth to a dynamic traffic load, i.e., maintain low duty-cycle in light traffic condition and schedule more transmission opportunities when traffic increases so that the energy is only used for carrying the application traffic whenever needed. When the load increases, the number of collisions and retransmissions strongly degrade their bandwidth efficiency and generate long delays.

Low duty-cycle is always used to improve the network lifetime in WSN. However, its disadvantage is long delay and low throughput if traffic is more. Authors in [9] proposed hybrid CSMA/TDMA MAC protocol called iQueue-MAC for dynamic and busy traffic. In this method if the traffic in a system is low then the protocol uses a contention-based CSMA mechanism that provides low delay with scattered transmissions and if traffic is more and dynamic then it uses a contention-free TDMA mechanism allocating transmission slots. iQueue-MAC mitigates packet buffering and reduces packet delay, combining the best of TDMA and CSMA. This system can be used in both multi-channel and single channel mode. iQueue-MAC is able to effectively use multiple channels, duplicating its throughput when compared to single channel operation. Authors also proposed a distributed sub-channel selection algorithm to assign unique sub-channels to routers to arrange the slotted transmissions in parallel.

For continuous transmission Wise-MAC [10] a contention-based protocols, uses a ”more-bit” information in the data packet header of data packets. RIMAC [11] Receiver-initiated MAC uses beacon as the ACK transmission and next forwarding for continuous transmission. RI-MAC and Wise-MAC have low throughput at heavy load because of collision between receiver and senders.

Z-MAC uses hybrid CSMA/TDMA procedure for static slot allocation and reduces traffic overhead. In this mechanism vacant slot can be used by others. Due to static slot allocation the bandwidth is reduced. Strawman MAC [12] reduces the contention by using extra Collision packets. The sender who has sent the longest Collision packet wins the channel. But the Collision packets introduce a considerable amount of overheads to the system. RCMAC [13] improves RI-MAC, that designates the next sender through ACK piggybacking to reduce collision. However, how to allocate bandwidth among senders is not specified.

CoSenS [14], a collecting then sending burst protocol was proposed to provide traffic adaptation. It dynamically adjusts the duration of its data collecting period according to the estimated traffic load. The traffic estimation algorithm is based on the weighted exponential average (similar to that used for RTT estimation in TCP protocol). ContikiMAC [15] efficiently integrates several unique techniques of other WSNs MACs, such as burst forwarding, phase-lock, and data packet strobe. However, ContikiMAC is mostly designed to handle low rate packets, it has no specific mechanism to handle burst traffic loads.

WirelessHart [16], ISA100 and the new IEEE802.15.4e standard are currently the most popular wireless solutions for industrial applications. These standards utilize Time Slotted Channel Hopping (TSCH) technique to provide deterministic transmissions and robustness. However, currently, they lack link scheduling algorithms which are crucial for assigning slots/frequency resources in WSNs.

Compared to existing solutions, iQueue-MAC mitigates contention and retransmission by shifting intensive senders into the TDMA slots period. The senders' queue-length information is piggybacked on data packet, so that the time slots are assigned right upon queuing detection. The crux of iQueue-MAC is an efficient closed loop control mechanism that uses nodes' queue-length as the measured output and uses adaptive time slots assignment as the control input to mitigate packets queuing. In fact, prior to iQueue-MAC, the similar idea emerged in the FTT (Flexible Time-Triggered) paradigm which is originally proposed for CAN and Ethernet, however, iQueue-MAC makes it more suitable for WSNs.

The different methods provided for dynamic slot allocation [17] comes at the cost of limited throughput, and additional packet delay. The sender is allowed to transmit in the short active periods, only with less energy efficiency. Thus, under high traffic load, the absence of collisions makes them very efficient supporting high throughput. However, if the offered bandwidth does not match exactly the communication requirements, either bandwidth will be wasted if nodes have nothing to transmit or queues will build up if nodes have more to transmit than what fits in the allocated slots, leading to long delays.

How to make available short delay, high throughput and less power consumption is main problem and research challenge in existing WSNs protocols. The different low duty-cycle protocols deliver low energy effectiveness under the assumption that the system has long-standing low rate intervallic traffic. Nevertheless, typical applications, in addition to low rate interrupted traffic, also require contemporary burst traffic generated upon occurrence detections, e.g., target detection. Consequently, there is a developing need for a protocol that get used to its obtainable bandwidth to a dynamic data traffic load, i.e., conserve little duty-cycle in low traffic condition and provide more transmission prospects when data traffic increases, and that the energy is only applied for carrying the network traffic on every occasion needed. The methods may have more traffic overhead and more energy consumption.

3. PROPOSED ALGORITHM

Keeping in view the above we propose an algorithm which caters for the requirements to improve the WSNs lifetime and throughput. The steps in the proposed algorithm are as follows:

Step1. Network initialization stage: Node chooses neighbors unique ID and broadcasts beacons for network establishment. Any node receiving beacons from different coordinators at the same moment will be tagged as the alternative gateway node, and the one with the nearest neighbor will be considered as the gateway by coordinators. All coordinators determine the position of their own and neighbors using gateway.

Step2. Nodes access stage: After nodes access to the network, they apply for the allocation time according to the step 3.

Step3. Nodes mobility tracking and prediction: When the position information indicates that the node has already moved to another network, the current associated network will inform the target node to reserve time slots for the coming node.

Step4. Nodes mobility support: If there are buffered packets in the former associated network when nodes enter into a new network, the former coordinator would forward those packets to the new one.

Proposed Algorithm

1) Initialization step: minq=0.20 * queue size
   Maxq=0.80 * queue size, Warn=queue size/2
   Threshold value setup
2) Each node checks its congestion statues by using average queue length, channel utilization ration and residual energy. Compute average queue length.
   The frequency of data packet is decided according to congestion status
   If frequency is high then
   Ok incoming traffic is low, no action is taken
   Else if frequency is medium, congested and neighboring nodes perform data transmission then
   Traffic is medium, low amount of data can be transmitted
   Else if frequency is low, high congestion in network then
   Traffic is high, alternate best path is dynamically established and data can be transmitted
   End if
3) Test data packet distribution ratio of the system
   If data packet distribution ratio drop to the given threshold then
   Starting source node arbitrarily pick the supportive address of any one node neighbor
   Send request to the nod
   If anyone node reply from other path except neighbor node then take the reverse locating program and direct check data packets
   Else
   Goto End
   End if
   End

The first step is initialization step. In this step, all the initialization parameters are set. The minimum queue is set to 20% of queue size. Maximum queue is set to 80% of queue size. Warning value is set to half of the queue size. Threshold value is set to .75.

In next step, each node checks its congestion statues by using average queue length, channel utilization ration and residual energy. It also compute the average queue length. The frequency of data packet is decided according to congestion status. If frequency is high then congestion is up to the mark i.e. incoming traffic is low, no action is taken. Otherwise if frequency is medium, congested and neighboring nodes perform data transmission then traffic is medium, low amount of data can be transmitted. Else if frequency is low, high congestion in network then traffic is high, alternate best bath is dynamically established and data can be transmitted.

The next step is to test data packet distribution ratio of the system If data packet distribution ratio drop to the given threshold then starting source node arbitrarily pick the supportive address of any one node neighbor. Send request to the node If anyone node reply from other path except neighbor node then take the reverse locating program and direct check data packets otherwise data can be transmitted.

4. IMPLEMENTATION AND RESULT ANALYSIS

We used Network Simulator 2 simulator software for implementation of proposed algorithm. We also used C/C++ and TCL language for implementation. We performed our experiment in Intel i3 4.0 GHz machine with 2GB RAM.

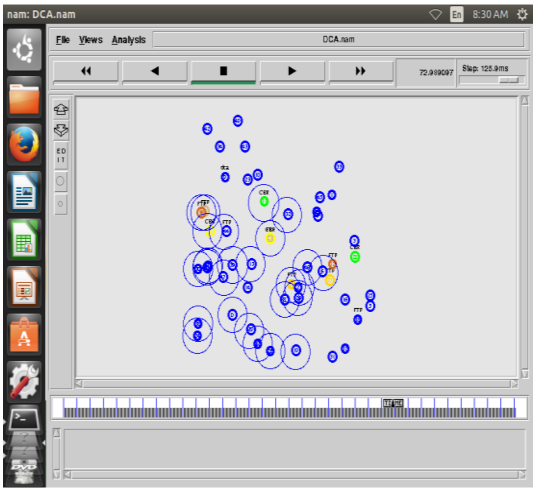

Figure 1: Channel searching at 72.9 second

Figure 1 represents the channel searching at 72.9 second. The different nodes are searching path for data transmission. We used 50 nodes for simulation of algorithm. Nodes mobility is also introduced to check the performance of the network. For this implementation, network parameters, such as Dimension, Number of nodes, traffic, transmission rate, Routing protocol, transmission range, sensitivity, transmission power etc., are used. Transmission range is specified as 300m. Movement model is used as random waypoint. Simulation duration is set as 90s. Traffic type is set as constant bit rate. Radio range is set as 250m. Data pay load is set as 512 bytes. The NAM is used for animation in implementation. Tcl script language with Object-oriented extensions.

Figure 2 shows the throughput analysis of the proposed system. The throughput is improved due to dynamic channel allocation.

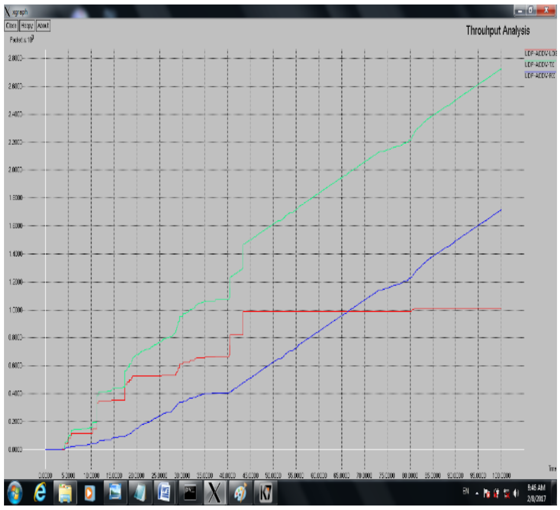

Figure: 2 Throughput Analysis

The congestion aims to drop the data packets or to hold the resources such that the communication is affected. The packets forwarding capacity of scheme is increased with period of time. As compared to all the reported related works the proposed work has the minimum packets drop ratio.

Table 1: Duty cycle

Our Method	IQueue	CoSens
17.16%	17.930%	27.472%

Table 1 shows the average duty cycle of nodes in experiment. As seen from the table our method has efficient performance in peak traffic time. The proposed method achieves 0.77% and 9.872% decrease in duty cycle as compare to iQueue method and CoSens methods, respectively. Also it takes around 5 ms of less time for data communication in the network. Due to small duty cycle, energy consumption of nodes decreases which, in turn, increases the lifetime of the network. Further, if we already know the traffic situation in the network we can decrease the power consumption of the network. In our work, we have checked the traffic situation using queue length status of the node. We also checked the packet dropped of the node so the system will discard the route information from the route status of the node. In the simulation, it was observed that the dynamic channel allocation method allocates better channel for data communication and thus improve the lifetime of the network.

5. CONCLUSIONS

A wireless sensor network encompasses of several lesser sized sensor nodes that have low working out power. WSNs have been the favorite choice for the succeeding generation monitoring and control systems. Wireless sensor networks have recently received increased attention for a broad array of applications such as surveillance, environment monitoring, medical diagnostics, and industrial control. The greatest noteworthy advantage of sensor networks is that they increased the computation ability to physical atmosphere where human beings cannot reach. How to provide high throughput and short delay, while still keeping low power consumption is still a research challenge in current WSNs MAC protocols. Low cycle duty cycle is always used to improve the network lifetime in WSN. Its disadvantage is long delay and low throughput if traffic is more. If the channel utilization is more than throughput of the wireless sensor network reduces. We proposed an algorithm which improves the duty cycle and lifetime of the wireless sensor network. The experimental outcomes represented the throughput of the system and end to end data transmission improved. The traffic of the wireless sensor network reduced due to dynamic channel allocation and overall system performance increased.

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