SPEED A Real Time Routing Protocol in Wireless Sensor Networks

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Abstract- Wireless sensor network is considered as the one of the important technology in today's world. In this paper a quality of service based real time communication routing protocol known as SPEED is mainly to be discussed. Real-time unicast, real- time area-anycast and real-time area-multicast are the three types of real time communication services are to be provided by the protocol. SPEED is a scalable and the highly efficient protocol for the sensor networks. End to End soft real time communication is gained by maintaining the proficient speed across network. Speculative analysis and the simulation results are to be calculated to authenticate our consequences.

Keywords: sensor networks, design issues, SPEED, results.

1. INTRODUCTION

Wireless Sensor Networks consists of very small sensor nodes that are characterized by restricted giving out power and energy resources. WSN have emerged as a promising tool for monitoring the physical world. In sensor networks, energy is a serious resource, while applications reveal a limited set of individuality [1]. Thus, there is both an opportunity and a requirement to optimize the network architecture for the applications in order to minimize the consumption of the resources. The necessities and boundaries of sensor networks make their architecture and protocols both challenging and divergent from the needs of fixed architecture [2].

Real-time (RT) wireless sensor systems have many applications especially in fire monitoring, medical care, intruder tracking and structural health diagnosis. WSNs have gained an enormous consideration for their ability in meeting the real time QoS guarantee in many critical scenarios. In wide-ranging, real time packet message guarantee can be categorized as i) Soft Real Time (SRT) ii) Hard Real Time (HRT). As the hard real time should support a deterministic dead time which implies, delivery of a message after the dead time is considered as a failure and sometime it may lead to a catastrophic effect. On the other hand, SRT supports probabilistic dead time that means there is some sort of latency in message delivery. Because of the highly erratic nature of wireless links, variable data packets relaying, energy and bandwidth constraints, a real time communication is a challenging task in case of WSNs [1]. In this paper a protocol named as SPEED is discussed that supports soft real-time communication based on stateless algorithms and feedback control for large-scale sensor networks. SPEED protocol is evaluated via simulation using MATLAB on the basis of various parameters like miss ratio, packet delivery ratio, energy consumption, throughput and delay.
Data delivery is the main function of the sensor networks. Basically, SPEED protocol distinguishes the three types of the communication patterns associated with the data delivery. Those are unicast, multicast and anycast.

2. DESIGN GOALS

1. Stateless Architecture. The large scale, high failure rate, and constrained memory capacity the physical limitations of sensor networks that necessitate a stateless approach. In SPEED there is no need of routing table it only maintains immediate neighbor in-formation.

2. Soft Real-Time. Sensor networks are mainly used to monitor and organize the physical world. SPEED protocol provides a uniform delivery speed across the sensor network and it meets real-time applications requirements such as emergency surveillance disaster in sensor networks [3].

3. Minimum MAC Layer Support. The feed-back control is provided in SPEED protocol. This scheme employed allows it to be compatible with all existing best effort MAC layers.

4. QoS Routing and Congestion Management. SPEED protocol is using a backpressure rerouting which reduces the traffic when blocking occurs. As in most re-active routing protocols can find routes that avoid network hot spots during the route acquisition phase and these protocols work well when traffic doesn't interrupt. However, these protocols are not as much of successful when congestion patterns change rapidly compared to the session lifetime. When a route becomes congested, such protocols suffer a delay.

5. Localized Behavior. These types of algorithms are defined as in which any action done by a node should not affect the whole network system. Mainly in the protocols a node uses flooding to discover new paths for routing. When the thousands of nodes in sensor networks wants to communicate with each other, and they follows the flooding procedure to find paths it may result in significant power consumption. To avoid that, all distributed operations in SPEED are localized to achieve high scalability.

6. Traffic Load Balancing. The band-width and energy are insufficient resources in sensor networks as compared to a wired network. Because of this condition, it is precious to develop a number of real-time paths to take packets from the source to the destination. SPEED uses non-deterministic forwarding to balance each flow among multiple synchronized routes.

3. SPEED PROTOCOL

SPEED, a QoS routing protocol for sensor networks that provides soft real-time end-to-end guarantee. The protocol requires each node to maintain information about its neighbors and uses geographic forwarding to find paths. And also maintains a preferred delivery speed across sensor networks by locally regulating packets sent to the MAC layer and diverting traffic at the networking layer.

The SPEED protocol consists of the various components:

- An API
- A neighbor beacon exchange scheme
- A delay estimation scheme
- The Stateless Non-deterministic Geographic Forwarding algorithm (SNGF)
- A Neighborhood Feedback Loop (NFL)
- Backpressure Rerouting
- Last mile processing

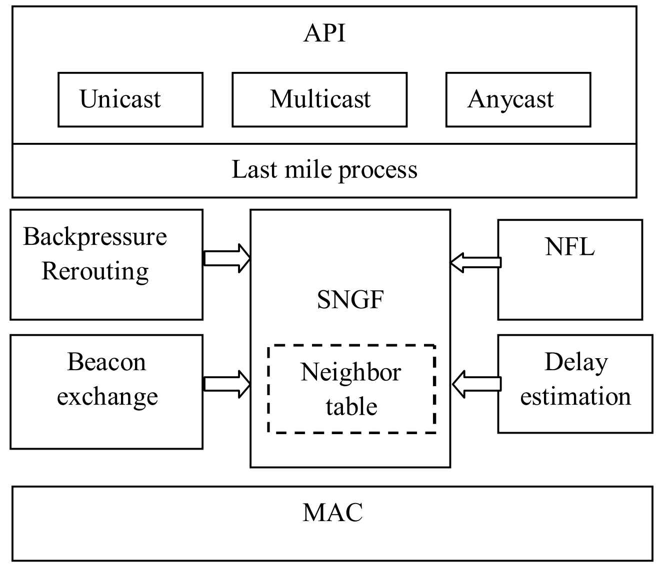

Fig. 1 SPEED Protocol

In figure 1 above the architecture of the SPEED protocol is shown. SNGF (stateless non-deterministic geographic forwarding) is known as the routing module in the SPEED and it works with other four modules at the network layer and it is responsible in charge for choosing the next hop. Beacon exchange provides the geographic location of the neighboring nodes so that SNGF can do geographic based routing. NFL and the backpressure rerouting are the two modules to reduce the traffic when blocking occurs [1]. The last mile process is provided to support the three unicast, multicast and anycast communication semantics. Delay estimation is the means by which nodes will determine that whether congestion has been occurred by waiting for the ACK from the receiving node. Here below the detail discussion of the components is done.

3.1. Application API

The real time SPEED protocol provides basically three types of application level API calls:

1) Area Multicast Send: This service depends on the position, radius and packet to be transferred. It identifies a destination area by its center position and radius. It sends a replica of the packet to every node inside the particular area of the network with a speed above a certain preferred value.

2) Area AnyCast Send: Similar to the area multicast this service also depends on the position, radius and packet. In this service to at least one node inside the specified area a copy of the packet is to be sending with a speed above an assured preferred value.

3) Unicast Send: In this service the node identified by Global_ID and the node having a particular Global_ID will receive the packet with a speed above an assured preferred value.

Real-time applications can estimate end-to-end delay before making admission decisions. SPEED protocol aims to provide a uniform packet delivery speed across the sensor network, such that the end-to-end delay of a packet is proportional to the distance between the source and destination. As the SPEED is a real-time protocol, so it can't use deadline as a parameter in API.

3.2. Neighbor beacon exchange

Every node in SPEED protocol periodically broadcasts a data packet to its neighbors. This periodic transmission is only used for exchanging location information between neighbors so that SNGF can do routing, Similar to other geographic routing algorithms. The beaconing rate should be very low when nodes are stationary or slowly moving inside the sensor network.

In SPEED protocol each node of the network is having the neighbor table in which it can store the information that is passed through the beaconing. The table of each node has the following identities that are: neighborID, position, expire time, SendtoDelay. The neighbor entries should be refreshed after a certain time period if it is not then it will be removed from the neighbor table. The expire time is used to timeout this entry.

3.3. Delay estimation

The delay estimation is the module by which nodes can determine whether or not congestion has been occurred. when the packets is to be transmitted to receiver node then after receiving the packet it will transmit the ACK back to the sender node. The delay is to be calculated at the sender, which timestamps the packet entering the network output queue and it will calculate the round trip single hop delay for his packet when receiving the ACK.

3.4 Stateless Non-deterministic Geographic Forwarding (SNGF)

The SNGF is the routing module in the SPEED protocol in charge for choosing the next hop for transmission of data packets. The three main definitions to be discussed are:

The neighbor set of Node i: NS_i the set of the nodes that are inside the radio range of node *i*.

The Forwarding Candidate set of Node i: a set of nodes that belong to the NS_i nearer to the destination. Further, the neighbor set depends on the radio range whereas the forwarding set of nodes depends on the destination also.

Relay Speed: it is defined as dividing the distance from the next hop by the estimated delay to forward a packet.

Based on the below discussed rules the SNGF routes the packets by considering the destination and the FS:

1) SPEED divides the neighbor nodes inside the FS_i into two parts. Firstly the nodes having the relay speed larger than a desired speed $S_{setpoint}$, the other one in which nodes that cannot sustain the desired speed.

2) Packets are to be transmitted to the only nodes that belong to the FS_i and if there is no node present in the FS_i, packet is dropped and the backpressure rerouting is applied.

3) The forwarding node is to be selected from the first group and the highest relay speed node is to be chosen as the forwarding node.

3.5. Neighborhood feedback loop (NFL)

The NFL is the important component in maintaining the single hop relay speed. It maintains system performance at a desired value. $S_{setpoint}$ and a drop are extremely essential to maintain the single hop delay. Such scheme ensures that re-routing has a advanced precedence than dropping. In other words, SPEED will not drop a packet as long as there is another path that can meet the delay requirements [6].

3.6. Back-pressure rerouting

Backpressure rerouting is used in a network to reduce the congestion, it is network layer adaptation used by SPEED. In this case there is no packet loss. Network layer adaptation has a higher priority than MAC layer. MAC adaptation is used by SNGF and NFL. When the situation becomes so congested a drop via the feedback loop is necessary and there is no other substitute to maintaining a single hop speed other than dropping packets. In this case, the neighborhood feedback loop is activated to assist backpressure re-routing.

3.7. Last Mile Process

SPEED protocol is only care about the location of the sensor data where it is generated. Since SPEED is targeted at sensor networks where the ID of a sensor node is not important. It is known as the last mile process because it will only be activated when the packet enters into the destination area. The SNGF module aforementioned controls all previous packet relays. It provides two novel services that fit the set-up of sensor networks: Area-anycast and Area-multicast. The area in this case is defined by a radius and the centerpoint (x,y,z), in essence a sphere. More complex area definitions can be made without design of this last mile process [7].

In case of an anycast packet, the nodes inside the destination area will deliver the packet to the transport layer without relaying it onward. In a multicast packet, the nodes of the destination area which first receive the packet coming from the outside of the destination area will set a TTL. This setting up of TTL allows the packet to survive within the diameter of the destination area and be broadcast within a specified radius. Other nodes of the destination area will keep a copy of the packet and re-broadcast it. The nodes outside the destination area will pay no attention to it. For unicast the last mile process is nearly the same as multicast, except in unicast the node is having the global_ID and with the help of the global_ID the node will deliver the packet to the transport layer.

4. RESULTS AND DISCUSSION

In this paper SPEED protocol is simulated by using MATLAB. In our evaluation, we present the following set of results: 1) miss ratio, 2) energy consumption 3) delay, 4) throughput, 5) packet delivery ratio.

4.1. Miss ratio calculation

The miss ratio is the most important metrics in the soft real-time systems. They set the desired delivery speed as $S_{setpoint}$ in the particular network.

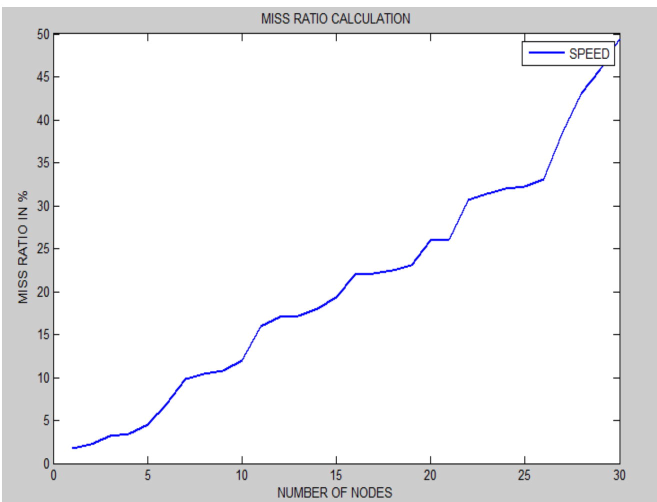

Fig. 2 Miss Ratio calculation with SPEED protocol

When the relay speed will be less than the $S_{setpoint.}$ The miss ratio of packets in the network starts increasing it is because when a large number of packets are transmitting from the source to the destination node through the various in between nodes of the network, some packets are lost due to congestion or forced drops. This dropping of packets is to be considered as the miss packets [8]. Figure 2 shows the miss ratio is in the network with the deployment of the nodes and in SPEED protocol the miss ratio percentage is not much high.

4.2. Energy consumption

The average energy consumption is the average of the energy consumed by the nodes participating in the transfer of data packets from the source node to the sink node. In the SPEED protocol, delay and relay speed are two important parameters in routing decisions. The nodes on special paths that have the least delay and the most relay speed die sooner than the others. As demonstrated in Figure 3 and Figure 4, by balancing the energy consumption on nodes, the network will be partitioned later and the network can be used longer. SPEED has slightly higher energy consumption.

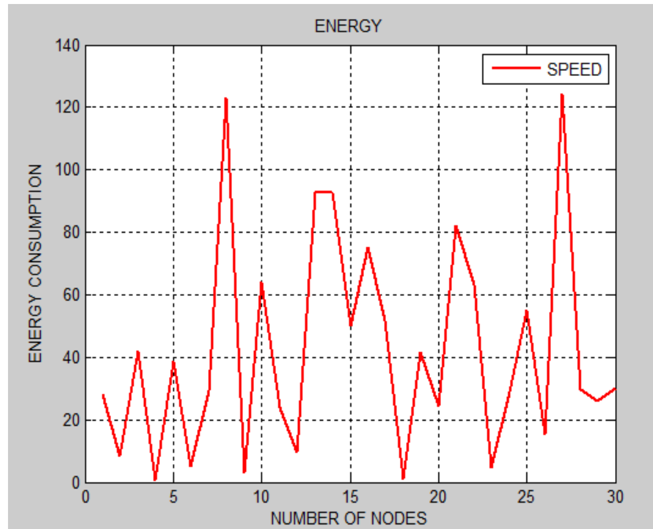

Fig. 3 Energy consumption with SPEED protocol

And the fluctuations in the energy consumption are there because of the heavy congestion in the network [8]. And to pass the data packets from that particular node there is a high value of energy consumption and if the needed energy is not provided then there is dropping of packets in the network and it will decrease the efficiency of the whole network.

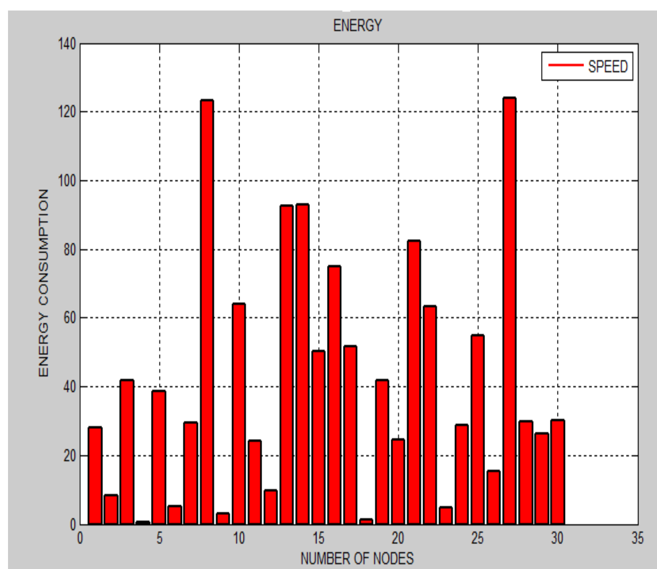

Fig. 4 Energy consumption with SPEED protocol

4.3. END to END delay

Delay is one important parameter for the real time traffic, which always must be considered. SPEED protocol guarantees end-to-end delay for the real time traffic. The end to end delay is defined as the time required transferring data successfully from the source node to the sink node. When the time used to transmit data is more than the actual time needed it is because of the delay. When node density is high and bandwidth is scarce, traffic hot spots are easily created. In turn, such hot spots may interfere with real-time guarantees of critical traffic in the network [8]. In SPEED, a combined network and MAC layer congestion control scheme is applied to alleviate this problem. Here the figure 5 shows the delay in the network due to congestion.

$d_{end\text{-}end}$= N[d_{trans}+d_{prop}+d_{proc}]

Where

$d_{end\text{-}end}$= end-to-end delay
d_{trans}= transmission delay
d_{prop}= propagation delay
d_{proc}= processing delay
d_{queue}= Queuing delay
N= number of links (Number of routers + 1)

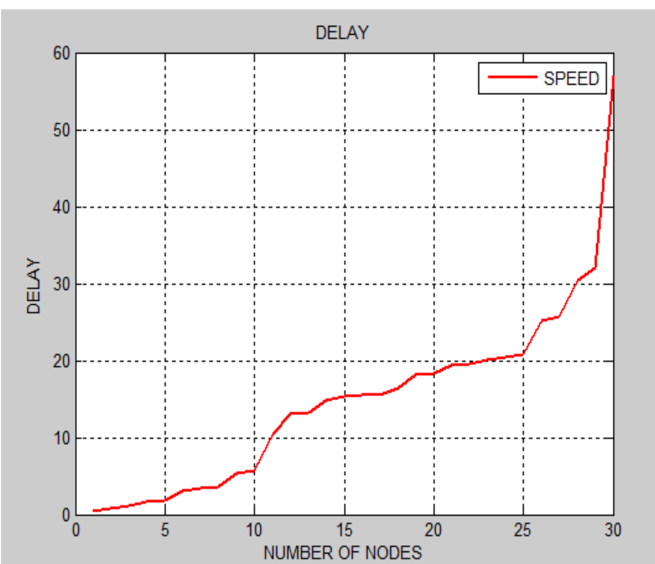

Fig. 5 END to END Delay

4.4. Routing Overhead

Like the energy consumption, the routing overhead is also a major consideration in the wireless sensor network. In actual, the routing overhead is defined as the node failure in the network. The energy will be depleted in special nodes which will cause the network to be partitioned and some node didn't get the energy that they required to forward the data packets and hence node failure occurred. Figure 6 shows the value of the routing overhead in the network as the SPEED protocol uses the backpressure rerouting and delay estimation, so when the congestion is will occurred it will be determined earlier by the delay estimation [9]. Because of which there is less chances of routing overhead in the network.

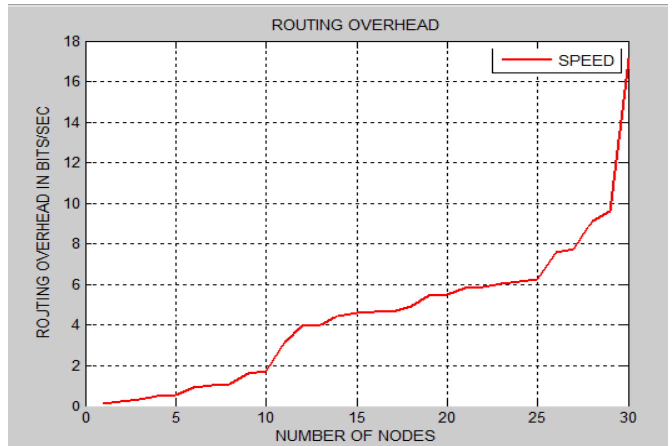

Fig. 6 Routing Overhead

4.5. Packet delivery ratio

When data is transmitting from the source to the sink node a high value of packet delivery ratio is needed. The packet delivery ratio is defined as the number of packets delivered to the destination node to the number of packets supposed to be received. Figure 7 shows the number of data packets delivered to the destination node and SPEED protocol provides a high delivery ratio [10].

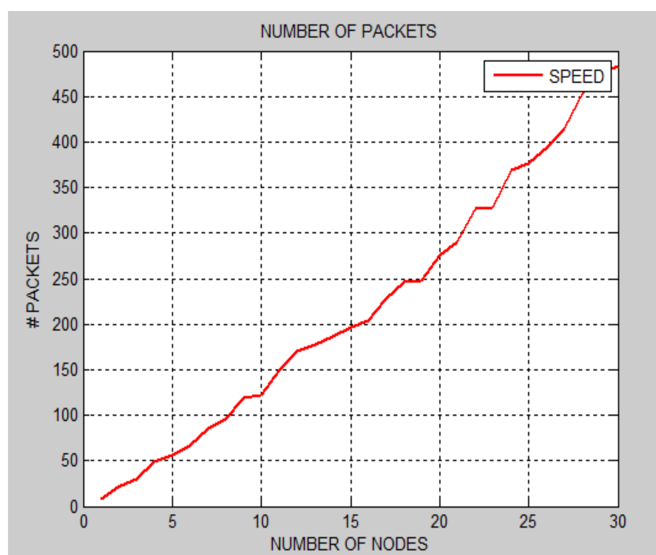

Fig. 7 Packet Delivery Ratio

5. CONCLUSION AND FUTURE SCOPE

In this paper, SPEED protocol concentrates on energy-efficient routing. The idea is to decrease the energy consumption and the high packet delivery ratio. Our result on the basis of MATLAB software shows that the SPEED maintains a desired delivery speed across the network through a novel combination of feedback control and non-deterministic QoS-aware geographic forwarding. This combination of MAC and network layer adaptation improves the end to end delay and provides good response to congestion and voids.

However, a problem should be considered in the SPEED protocol, furthermore in future, work can be extended that how assure the successful delivery of the data packets in a network and enhancement of these parameters. In future the routing of SPEED protocol can be optimized with the help of any algorithm to increase the network lifetime, throughput and other parameters that will meet the real-time applications needs.

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