RESEARCH ARTICLE OPEN ACCESS

A Survey on Congestion for Wireless Sensor Network

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ABSTRACT
Due to recent advancement in MEMS (micro electro mechanical system) technology, building of sensor has been made possible. Wireless sensor network (WSN) is highly distributed network of low cost, low-power, multifunctional sensor nodes that are small in size and communicate with each other to monitor environment or system. The primary objective wireless sensor network is to sense the data and send it to base station. Due to high volume of sensed data and limited memory of sensor node congestion could occur which leads packet loss and hence retransmission of packets becomes necessary. Retransmission leads to excessive energy consumption. Therefore congestion in WSN needs to be controlled in order to extend the system lifetime. It is also required to provide QoS and improve fairness in WSN for various applications. There are two type of congestion control technique in WSN, Traffic control and Resource control.
***Keywords* —** WSN (wireless sensor network), Congestion**.**

I. INTRODUCTION

In wireless sensor network (WSN), Sensor nodes measure physical quantity such as temperature, pressure, humidity, motion, characteristics of objects etc. A typical WSN consist of several hundred to thousand sensor nodes typically scattered around a sensing field. These nodes collect information about their surroundings and send to Base Station (BS). BS may further be connected to large network like Internet, Cellular or Satellite network.

Wireless sensor network are used in many applications which require continuous check and detection of any event such as Military application, Environmental application, Health applications, Home application, Multimedia application etc. The important challenge in the design of wireless systems for WSN is the communication bandwidth and energy which are limited. There is sudden burst of data when any event takes place in sensing environment. Due to high volume of sensed data and limited memory, sensor node experience congestion which leads packet loss and hence retransmission of packets becomes necessary.

In WSN, when at any node the incoming traffic exceeds the resource amount available to the node congestion will happen. In other words,

$$\Sigma \text{ Demand} > \text{available resources}$$

Resources could be buffer capacity and available bandwidth. If the buffer space available at the destination is less than that required for the arriving traffic, packet loss will occur. In the same way, the link is said to be congested, if the total traffic wanting to enter the link is more than its bandwidth.

A. Based on location of congestion: [15]

Depending on the location of congestion, congestion can be classified into three categories

- Packet losses will occur which in turn degrade network throughput.
- Large queuing delays are experienced as the packet arrival rate exceeds the link capacity.
- The sender must retransmit packets if buffer overflow and packet is dropped. Retransmission increases energy dissipation.
- Congestion will increase Packet service time and decrease link utilization.

Therefore congestion must be efficiently controlled in wireless sensor network.

This paper is organized as follows. Type of congestion in WSN is described in section II. In section III congestion control approach for WSN is described and Section IV represents the conclusion of the study.

II. TYPE OF CONGESTION

Congestion in WSNs can be classified in two major categories concerning location of congestion and causes of congestion.

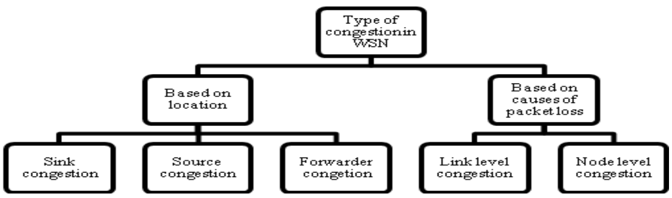

Fig 1 Type of congestion in WSN

1. Source congestion

When any event occurs, all the sensors whose sensing ranges (with radius r) cover the event spot will detect it. These nodes will act as sources. As node's radio range (R) is usually greater it's sensing range, these sources will be within each other's radio range as well. If all these source nodes, at the same time start sending packets to the sink at high rates, then a hot spot will be formed around the sources and within this hot spot a large number of packets will be dropped.

This type of congestion can be controlled by careful scheduling between these sources which allows only a small number of nodes (out of all the nodes within the event range) to report to the sink. This has two main advantages. First, the data traffic within the event range will be considerably reduced while not affecting the accuracy level seen by the application at the sinks because these nodes will be reporting the similar data. Second, if we only allow small number of nodes to be active (i.e., both sensing and communication) at any time period, then we can save a good amount of energy, and further extend the network lifetime.

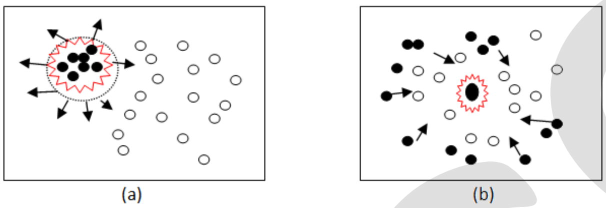

Fig 2(a) source congestion and 2(b) sink congestion

2. Sink Congestion:

When the sensors accounts an event at a high data rate, sink nodes (and the nodes around them) will sense a high traffic volume. If a hot spot occurs around a sink, the packets will be lost inside the congested area near the sink, and dropping of a packet around the sink has consequences. Resulting in a much dire impact on the entire network lifetime as an extensive amount of energy has already been consumed by the nodes along the routing path in distributing the packet from the source. Another result of side effect is that the battery power of all the nodes that are around the sink will be exhausted quickly, making the sink inaccessible from the rest of the network. Therefore, an effective way of eliminating sink congestion is to place multiple sinks that are equivalently scattered across the sensor field.

3. Forwarder Congestion:

A flow means to a couple of source and sink and all the subsequent intermediate forwarding nodes. A sensor network will have multiple flows, and these flows will interconnect with one another. The area surrounding the intersection will possibly become a hot spot. Keeping in mind that intersecting flows do not essentially have separate sources and sinks as they can share the same source or sink and hence sharing the segment(s) of the routing path. For example every intermediate node in the tree can suffer from forwarder congestion in a tree-like communication theory. Comparing the above two scenarios, Forwarder congestions are more difficult as it is very difficult to calculate the intersection points due to the network dynamics.

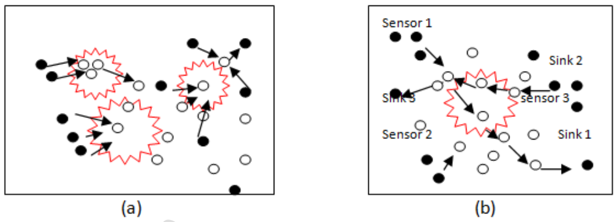

Fig 3 Forwarder congestion: (a) Intersection hot spot merging traffic and (b) Intersection hot spot crossing traffic

B. Based on causes of congestion:

Depending on the causes of congestion, congestion in wsn also classified into two categories.

1. Node level congestion

Node-level congestion that is caused by buffer overflows in the node and can result in packet loss, and increased queuing delay. Not only can packet loss degrade reliability and application QoS, but it can also waste the limited node energy and degrade link utilization. In each sensor node, when the packet arrival rate exceeds the packet-service rate, buffer overflow may occur. This is more likely to occur at sensor nodes close to the sink, as they usually carry more combined upstream traffic.

2. Link level congestion

The second type is link-level congestion that is related to the wireless channels which are shared by several nodes using protocols, such as CSMA/CD (carrier sense multiple accesses with collision detection). In such case, when multiple active sensor nodes try to occupy the channel at the same time, collisions could occur.

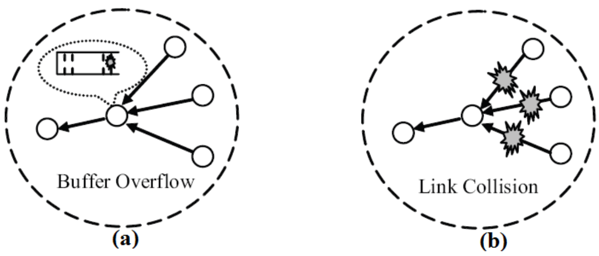

Fig 4(a) node level congestion and 4(b) link level congestion

III. CONGESTION CONTROL

Congestion control protocol efficiency depends on how much it fulfil following criteria:[9]

- Energy-efficiency requires to be improved in order to extend system lifetime. Therefore congestion control technique should avoid or reduce packet loss due to buffer overflow, and remain lower control overhead that consumes less energy.

- Congestion control technique need to maintain traditional QoS metrics such as packet loss ratio, packet delay, and throughput. For example, some multimedia applications in WMSNs require packet loss guarantee as well as delay guarantee.

- Fairness needs to be guaranteed so that each node can achieve fair throughput. Most of the existing work [11] [10] guarantees simple fairness in that every sensor node obtains the same throughput to the sink. In fact, sensor nodes might be either outfitted with different sensors or geographically deployed in different place and therefore they may have different importance or priority and need to gain different throughput. Therefore weighted fairness is required.

There are mainly three parts for Congestion control

1. Congestion detection
2. Congestion notification
3. Congestion control

1. Congestion detection

One of the main problems in designing a congestion control strategy for WSNs is how to detect congestion. In the Internet, conventional congestion detection techniques depend heavily on packet loss due to buffer overflows to infer congestion, and to a lesser extent on queue occupancy, and end-to-end delay. As energy is main constrain in WSN, traditional techniques cannot be used. In WSN congestion can be detected by several ways like buffer occupancy, channel sampling and packet service rate & scheduling rate

(i)Buffer occupancy:

In this method congestion is detected when the instantaneous queue length of a node exceeds its limited buffer capacity, leading to packet drops, or when the queue length exceeds a certain threshold value of the buffer capacity, leading to long delays.

(ii)Wireless Channel load:

In this technique, when a packet waits to be sent, the sensor node samples the state of the channel at a fixed interval. Based on the number of times the channel is busy, it calculates a utilization factor. If utilization rises above a certain level (e.g. the theoretical upper bound of the channel throughput), the congestion bit is set. Otherwise, the congestion bit is cleared.

(iii)Packets inter arrival and service rate:

In this method congestion is detected by inspecting packet inter-arrival time and packet service time (or alternatively incoming and outgoing traffic rates).In these approaches, congestion is inferred when the inter-arrival time is smaller than the service time, that is the incoming packet rate is higher than the outgoing traffic rate leading to accumulation of packet in queues and there might be congestion if buffer overflow.

2. Congestion notification

After detection of congestion, the entire network is notified to take measure for congestion control. Congestion notification is divided in to two categories: explicit and implicit notification.

(i)Explicit:

Using explicit congestion notification, control packets are sent by congested nodes to the rest of the nodes to inform them about congestion. It has been proven that sending control packets when congestion has occurred, adds significant load to the already congested environment. Therefore, explicit congestion notification has not been adopted by subsequent congestion control protocols.

(ii)Implicit:

In this method congestion information is propagated to the rest network by overhearing data packets which are on fly. If congestion is detected, a notification bit is piggybacked in data packet’s header or in ACK packets (when used). Implicit congestion notification avoids the addition of extra packets to the network when it is already congested.

3. Congestion control

There are general two approaches for congestion control: resource control and traffic control.

(i)Resources control:

In this approach to mitigate congestion network resources are increased. In wireless network, power control and multiple radio interfaces can be used to increase bandwidth and weaken congestion. For example, sinks are allocated two radio interfaces: one primary low-power node radio with smaller bandwidth and another long-rage radio with larger bandwidth. When congestion occurs, the long rage radio is used as a shortcut to mitigate congestion. With this approach, it is necessary to guarantee precise and exact network resource adjustment in order to avoid overprovided resource or under-provided resource. However this is a hard task in wireless environments.

(ii)Traffic control:

Traffic control implies to control congestion through adjusting traffic rate at source nodes or intermediates nodes. This approach is helpful to save network resource and more feasible and efficient when exact adjustment of network resource becomes difficult. Most existing congestion control protocols belong to this type.

There are two general techniques for traffic control in WSNs:

(1) End-to-end: In end-to-end control technique, exact rate adjustment at each source node is done and simplifies the design at intermediate nodes; however, it results in slow response and relies highly on the round-trip time (RTT).

(2) Hop by hop: The hop-by-hop congestion control has faster response. However, it is usually difficult to adjust the packet forwarding rate at intermediate nodes mainly because packet forwarding rate is dependent on MAC protocol and could be variable.

III. CONCLUSION

Congestion control is an important issue that should be considered while designing wireless sensor network to save scare resources. After studying type of congestion and congestion control techniques existing congestion control techniques are compared based on its congestion detection, notification and rate adjustment method as shown in Table 1.

TABLE I
COMPARISON OF VARIOUS CONGESTION CONTROL TECHNIQUE

Technique	**Congestion detection**	**Congestion notification**	**Rate adjust-ent**
PCCP[3] [9]	Packet inter arrival and service time	Implicit	Exact hop by hop
ECODA [6]	Dual buffer threshold and buffer difference	Implicit	Hop by hop
FACC[7]	Packet drop at sink node	Explicit	hop by hop
PHTCCP [8][2]	Packet service rate and scheduling rate	Implicit	hop by hop
Fusion [10]	Queue length	Implicit	hop by hop
CCF[11]	Packet service time	Implicit	hop by hop
CODA [12]	Queue length & channel status	Explicit	AIMD

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