A Survey of Reliability Schemes in WSNs

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Abstract: ***A well design of any reliable wireless sensor network must address the requirement of applications and must be able to solve all the issues raising at various levels. The issues and requirements of reliability improvement mechanisms relies on the available resources and application for which the WSN is deployed. This paper presents a survey on several existing reliability models. Wireless Sensor Networks are still distrusted with respect to reliability. Many researchers have proposed different mechanisms to ensure desire reliability in wireless sensor network. Most of the present schemes employ to reduce packet loss ratio, end to end retransmissions, maximizing information that reaches to the sink & eventually optimizing several parameters of WSN by taking into account trade off between them.***

Keywords: Reliability, Wireless Sensor Network, Trade-off

1. Introduction

Wireless sensor network often comprised of spatially distributed nodes connected to each other in co-operative manner which monitors the environment to which they are belonging. Each node in a wireless sensor network is well equipped with one or more sensors with additional components like transceiver, microcontroller & power source. The most adorable characteristic of wireless sensor network is its autonomy. When installed in the field, the microprocessor automatically initializes the way every node will be communicating with other nodes falling in range, it creates an ad hoc mesh network for relaying information to and from the gateway node. This negates the need for costly and ungainly wiring between nodes& tends to be an more economical with few exceptions, Hover over wireless sensor network allows nodes to be deployed in almost any location, which offers great flexibility as well as much more potential for application-specific solutions. The continual emergence of new architectural techniques in wireless sensor network as well as its usability i.e. WSN is a solution for many of problems. WSN serves many applications where requirement of each application is need not be same. One common key requirement of any application is the reliability. Reliability is such requirement which decides how efficiently a particular application is serving the purpose. The motivating & interesting aspects of WSN are providing required services of application with the consideration of its characteristics, Design issues &eventually limitations of its scarce resources.

This paper discusses several available transport protocols for betterment of reliability in WSN. Any protocol of transport layer must serve the intended purpose and must fulfill certain requirements. When you think to develop a protocol at transport layer it must conform the design requirements of transport layer. The transport layer protocol of WSN should generalize by means of its independence with respect to the application, Network layer protocols as well as MAC layer protocols. If a transport layer protocol reveals high dependency over the network topology let's say a tree-based topology; it may not be suit to such applications that are habitual to a flat topology. A transport protocol should be positive at both continuous as well as discrete data flow in the network. Continuous means streaming data which needs fast response rate via control algorithms to restrict the speed of stream flow to avoid congestion in WSN. Discrete i.e Event-driven flows need lower requirements on the rate control but it requires a highly reliability to capture the event. In simple words no data loss is tolerable. Few applications require full reliability while others might tolerate the loss of few packets. The transport layer protocol should take benefits of this fact and should save energy at the nodes by avoiding retransmissions wherever loss of few packets is tolerable. The congestion detection as well as congestion avoidance mechanism is the most important factor in a transport protocol. Congestion detection is a well known difficult task in WSNs because the congestion exists at only certain part of the network. Since sensor nodes are with less energy as well as confined due to the less computational power, majority of the tasks and computational tasks are done by the base station. Sensor networks may be consists of abundance of nodes; hence the protocol should be scalable. The protocol should be adaptable for the fourth time optimizations to improve network efficiency as well as to support new applications.

2. Previous Work

Efficient Multimedia Transmission in Wireless Sensor Network:

Author here addressing few mechanisms which will explore how transport layer in WMSNs could make use of certain information taken from application layer to improve overall performance. To reveal it they have considered previously proposed reliable transport protocol (DTSN- Distributed Transport For Sensor Network) as a hypothesis. By modifying the behaviour of DTSN a new protocol has been proposed called M-DTSN (Modified- Distributed Transport for Sensor Network).The fundamental approach is when in between two peers transfer takes place of video information the smallest unit for a receiver is an image frame. The receiver is able to render a frame when it arrives before the rendering instant of the frame. If transmitter couldn't send this frame in time i.e. before the rendering instant it would be no worth in sending this information. This is what exactly paper exploiting key idea to improve the performance of the multimedia transmission. Before this lets see in brief the behavior of DTSN.

Proposed Mechanism of Multimedia Transmission:

Three assumptions to be made:

- Multimedia flows are time-constrained
- Sensors has limited amount of energy for the transmissions
- Data link layer /MAC reliability is often not enough to guarantee the required delivery success ratios, and even Forward Error Correction (FEC) codes may not be effective in ratio channels featuring busty error patterns.

In this scenario they are suggesting a transmission mechanism to improve the efficiency & effectiveness of current transport protocol i.e. DTSN. To manifest it they have considered figure 1 where you can see three back to back frames are transmitted by sender. Please note that all frames are of equal size S & required time to transmit them may be different. This same assumption is made for three of those strategies i. e. S-DTSN, DTSN&M-DTSN. In Simple DTSN (S-DTSN) the transport layer receives each frame at interval I that means every interval I a new frame is delivered to the receiver. All these frames are transmitted one by one.i.e. sequentially in such fashion the next frame is not sent until and unless the transmission of next frame is completed. As you can see in the figure the fame 1 in S-DTSN remains more than I seconds which infers some of the information is useful as frame 1 makes its arrival at interval time which is reserved for reception of the new frame where 't' belongs to [0, I].The information received after time interval I is taken as useless information. In figure white-bar & black-bar reveals useful information as well as useless information respectively. The useless in formation doesn't contribute in video streaming hover over it causes delay to other frames. In figure the delay introduced by frame 1(useless information) causes delay even to frame 2.

The DTSN follows the behaviour of S-DTSN but in DTSN the transmitter is slightly modified as it knows the frames required by the receiver & it can discard the previously waiting frames if they are not transmitted. To understand this more clearly consider the figure 1 where DTSN notice before transmitting frame 2 that instance for rendering frame has already occurred so without sending frame 2 it will sending frame 3 which will be rendered at t=3.I.DTSN here causes energy saving as it doesn't transmit the frame 2 & also the receiver can render at least one of the frames.[2] The M-DTSN which is a proposed idea to improve the transmission efficiency. Here transmitter transmits information under such impression where information would not remain more than I seconds. Transmitter stops transmission once I seconds are elapsed. In figure 1 the frame one is rendered exactly at interval I& transmission of next frame started & so on. In M-DTSN two of the frames are received completely while the reception of first frame is not complete thus it would be useless.[1][3].

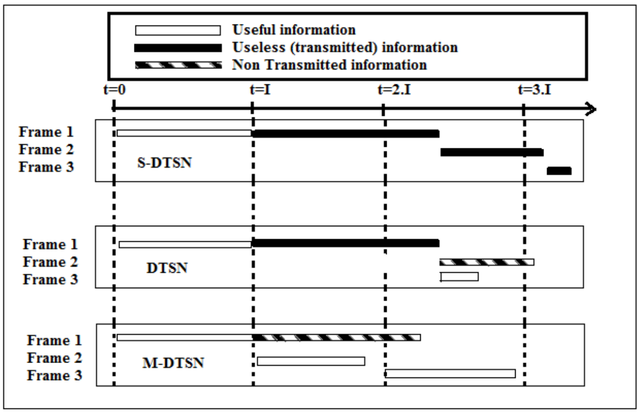

Figure 1: Shows the reception of frames at the receiver with respect to S-DTSN, DTSN & M-DTSN

Differentiated Reliability for Wireless Multimedia Sensor Networks:

This paper proposes an extension to DTSN protocol to comply with the memory limitation without compromising throughput.[4] [5] Traditionally in DTSN source has to remember full packet blocks in order to retransmit them in case if receiver doesn't receive them. To relief source from this trivial burden the proposed protocol make source to remember only important packets. The interested reader can prefer to [6] for a deep survey on WSN transport protocols. Author with respect to the survey of RMST [7] claims it requires significant memory resources. Question comes in mind like how to differentiate packets in order to identify only important amongst those? Of course here source will be remembering those transmitted packets only which belongs to the most important layers. For the other packets, error recovery is eventually performed by the intermediate nodes.

DTSN Differentiated Reliability Extension:

Fig. 2 shows an example of the extended DTSN protocol where in this example node 0 & node 3 would be the sender & receiver respectively. The nodes 1 and 2 are considered as intermediary nodes. Node 0 transmits a window of 6 packets, amongst them packets 1, 2, 3 belong to the base layer where as Packets 4, 5 and 6 belong to the enhancement layer. The packets 1,2& 3are only the packets which node 0 keeps in its transmission window (M0). In figure 2 packet 1 is transmitted successfully via intermediate nodes without any failure. While transmitting packet 2 none of the intermediate node cache the packet 2 which is similar case with packet 4. Let's assume node 1 has stored the packet 5.Now the EAR considers its of no use to request the packet 4. Packet 5 is retransmitted by node 1 while packet 2 is retransmitted by node. Node 3 generating a new packet to indicate next expected sequence number is 7. Author has implemented the DTSN protocol & incorporated the extension of partial reliability on the ns-2. [9]

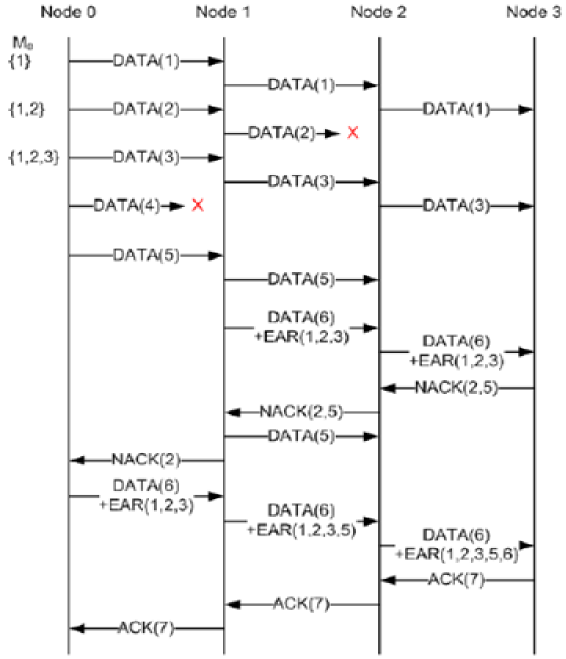

Figure 2: Example message diagram of DTSN with the differentiated reliability extension

A Transport Protocol for Congestion Avoidance in Wireless Sensor Networks Using Cluster-Based Single-Hop-Tree Topology:

This paper proposes a transport protocol in wireless Sensor Network with noisy environment which avoids congestion. To achieve this they have used cluster-based single hop tree topology. Here WSN is divided into abundance of clusters having varied quantity of sensors. The density of the clusters is totally dependent on the accuracy required. Here sensors are arranged in tree topology where each leaf sensor will be sensing information from the environment & will be passing the received information to the corresponding parent node & so on up to the sink node. This process goes on continuously until the sensors stored values converges to the predefined values.[10]

The existing transport protocols in WSNs mainly deal with congestion control, reliability & priority scheduling. Many of them protocols are using single hop networks.[11] Author have proposed protocol called as a Single Hop Cluster Tree Congestion Avoidance Estimation Protocol (SHCTAE) which is used to avoid congestion in noisy environment where all identical sensors are arranged in cluster based tree topology. The root of the tree is called as a sink node which collects the information from its all subordinates. Here parent can have any number of children's. The depth & the breadth of the tree is merely dependent on the geographical area which is supposed to be sensed by sensors. So we can make inference the number of sensors required is equal to the area to be sensed by the sensors. Note that each node is a cluster head of that cluster which represents set of sensors. Each sensor in tree will be having information regarding to its cluster head. The number of clusters in cluster head can be different. Here sensors are arranged in tree topology. The information sensed by leaf sensor is transmitted to specific set of sensor in spite to all members of that cluster. They will be in direct single hop transmission whereas sensors belonging to the different clusters may not be in range of direct transmission. In one time cycle each sensor will sense its environment, going to measure the intended parameters & will be storing them into small memory. After this all sensors stop sensing & processes the averaging of measurements & resumes sensing the environment. This way each sensor at each cycle calculates new value & replaces previously stored values. This process goes on until all are the sensors converges to the some predefined value. The replacement is done on the basis of a formula, suppose after few iteration the value in the nodes are considered as a "Eav" and in the next iteration the value is replaced by Eav1 now if (Eav1- Eav) <= δ [where δ= 0.01, called as a typical acceptable error margin, then the process will stop and Eav1 is considered as the true value else the process of gossiping will repeat.[8] Thus it results into maximization network lifetime.

Trading Transport Timeliness & Reliability for Efficiency in Wireless Sensor Networks:

The one of important task in wireless sensor networks is to deliver the data from sensor nodes to the sink. Plenty of applications require this delivery to the sink node in reliable as well as in timely form. There are several protocols for such provision [12][13][14] With respect to data transport in WSN either concentrates on reliability [15][16][17][18][19][20][21] or timeliness [22][23][24][25][26][27] or both [28][29][30][31]However, this leads to the cost of higher energy use as in both situations an additional texts have to be set like retransmissions to achieve reliability and optimal path to achieve timeliness. This author's aim is tuning reliability and timeliness in order to achieve a maximized efficiency. Their approach's has taken requirements of reliability & timeliness as an input to meet up user requirements.

To do so they come up with two approaches:

- Getting number of optimal retransmissions per hop with delay compensation
- Path split and/or path replication if reliability or timeliness either of requirements are violated.

The author has come up with two algorithms i.e rT algorithm which gives tunable timeliness with best effort reliability. This algorithm will be finding the optimal numbers of retransmissions are required in a per hop basis & implements delay compensation on a per hop basis. If delay compensation is not useful, a path replication and/or path splitting is conducted. The second algorithm is RT algorithm that gives tunable reliability and timeliness that too in composition. RT is an a extension of rT algorithm. RT is used when delay compensation as well as path replication and/or path splitting is not that effective.

The key approach or you may say key idea of this paper has been explained by means use of three scenarios which are clearly revealed in figure 3. [4]

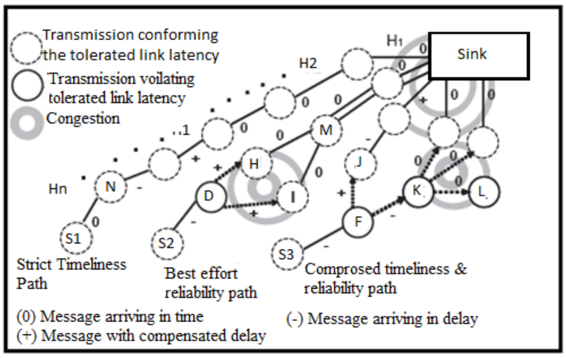

Figure 3: Three illustrative scenarios for the proposed information transport

In order to get a fully distributed solution, author has proposed decisions must be made per hop basis. For instance, it has been proven that per hop reliability in WSN outperforms the acknowledgment and retransmissions. Accordingly, hop-by-hop retransmission towards the sink is the standard approach. So we can conclude entire reliability of network is divided across multiple hops on the path. Similarly author has proposed design of timeliness strategy on a per hop basis. The scheme of tunable reliability is modified by means use of appropriate retransmissions per hop allowed at tolerable link latency. Sometime all retransmissions are required with no modifications. If on a hop Hi the number of needed retransmissions are not at all possible without violating the LtoHi, then proper countermeasures are needed. Author has discussed the following, where they have deeply discussed these developed countermeasures, which represents their proposed idea. The three basic circumstances illustrated in Figure 3 where the information is sent by S1, S2 and S3.

Delay Compensation: Let's assume S1 which is generating information and sending it to the sink. Author has assumed that in between nodes require a number of retransmissions which are violating the tolerated link latency & if the causing delay wouldn't exceed a value (say delta) of the tolerated link latency of the upcoming next hop, for which delay compensation is needed. This scheme ensures strict timeliness with best effort reliability. Delay Compensation with Path Split: Assume S2 has made delay compensation; however, Node D is not able to do delay compensation anymore as it may cause the link latency which would exceed the tolerated latency of the next hop. Accordingly author has proposed a mechanism which will split the path to ensure Rdhop within the required L to Hi. Here we refer to path split means sending the same message to the neighboring nodes. Delay Compensation with Path Replication: In S3 scenario node F will be requiring delay compensation as well as path split across two neighbor sensor nodes i.e. J and K. As delay compensation as well as path split are not effective at Node K. Thus, Node K will be requiring conducting path replication to three neighboring sensor nodes. Please note that here number three is completely based on the number of retransmissions left. Path replication reflects sending the same message to the two or neighboring sensor nodes. All the three scenario reveals how proposed system will working more efficiently which will be finding the trade-off between the reliability & timeliness on one side & reduces number of retransmissions on another side through delay compensation, then path split, then path replication if required.[32]

Improving energy saving & reliability in WSN using a simple CRT-based packet forwarding solution:

In this paper author proposes a forwarding scheme for WSN which combines the aim of low computational complexity & high performance with respect to energy efficiency & reliability. Author proposes a packet splitting algorithm which is completely based on the Chinese Remainder Theorem (CRT).

The proposed approach simply divides the original message into many packets in such a manner each node in the network will be forwarding only small sub-packets. This splitting is done by using CRT algorithm which characterized by simple modular division between integers. All sub-packets (called CRT components) once received correctly the sink node simply recombines them in order to form original message. Author has introduced few main considerations in his system by taking into account erasure channels, MAC-layer overhead & eventually actual computational resources required by nodes.

To bring more clarity author has considered a sensor network where each of the node send periodically messages to a base station. Consider the figure 4 Nodes A & B want to send a packet to the base station S. To do so node A & B can send that particular packet via X,Y& Z. If normal forwarding scheme is used two cases can be differentiated:

Case 1] A & B can select different next hop nodes with probability of 2/3.
Case 2] A &B can select the same next hop node with probability of 1/3.

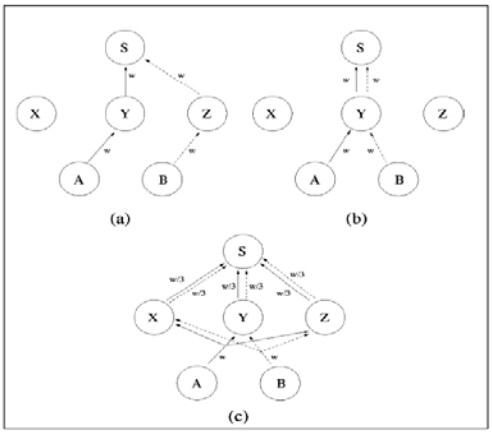

Figure 4: Message forwarding scenarios

If the message is in size of 'w' bits then the number of maximum bits transmitted by a node amongst X,Y& Z is 'w' bits in case1 & 'w/2' bits in case2. Let's assume now that node X,Y & Z knows that A & B have three choices to forward the packet which is exactly the case in fig 4 [c] where each of node transmits maximum '2/3w' bits. If we compare different packet forwarding schemes presented in fig 4.the last one reduces the maximum number of bits to be transmitted by a node i.e. [c]. [33]

3. Observations

A lot of research is still getting carried out to come up with effective and low cost localization algorithms in wireless sensor network especially in noisy environments. The main barrier in wireless sensor network for its research is limited available resources as well as the trade-off relation between them. WSNs dealing with many new applications to satisfy their own requirements with the consideration of its challenges Various transport protocols are optimized in order to achieve reliability but still desired reliability is an issue. Algorithms with low complexity needed to be develop to address the exact reliability requirement of a certain application. To bring more reliability researchers now focusing to make existing systems more general & more variable up to certain extend. Any application often need reliability but the question is up to what level ? It is important to bring some intelligence in WSNs as well as to hike its dynamic ability while dealing with distinct requirements of certain applications.

4. Comparison

Table 1: Comparison of approaches with pros and cons

Paper Title	*Approach*	*Pros*	*Cons*
Differentiated Reliability for Wireless Multimedia Sensor Networks,2012, IEEE	Allowing source to memorize only the important packets to comply with memory limitations	Energy Efficient, Flow Control, Error Recovery	Reliability is less No mechanism for congestion avoidance, Protocol is not adaptive
Trading Transport Timeliness & Reliability for Efficiency in Wireless Sensor Networks,2013, IEEE	Tune reliability & timeliness to maximize efficiency	Offers Reliability Avoids Congestion Adaptive in nature	Not energy efficient, No consideration of sampling accuracy attributes
Efficient multimedia transmission in wireless sensor network	Modifying the behaviour of previously proposed reliable transport protocol “Direct transmission for sensor network”	Reliability, Energy efficiency is moderate, Loss recovery, Flow Control.	Absence of adaptive algorithm to select proper configuration values.
A Transport protocol for congestion avoidance in Wireless Sensor Network Using Cluster-Based Single Hop Tree Topology	Uses cluster based single hop tree topology for congestion avoidance	Energy Efficient Avoid Congestions, Loss Recovery.	In absence of explicit mechanism no loss recovery & congestion avoidance, Monitors only slowly changing Environment’s
Improving Energy Saving and Reliability in Wireless Sensor Using a Simple CRT-Based Packet-Forwarding Solution	Chinese Remainder Theorem for packet splitting	improves Energy Efficiency & Reliability	Overhead of MAC header. Modular division need several clock cycles

5. Acknowledgement

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6. Conclusion

In this paper we have discussed different reliability schemes for wireless sensor network. Each scheme has its own pros and cons. Researchers has focused more to optimize the utilization of valuable resources of WSN. Though various schemes have been proposed still WSN distrusted due to its enough lack of reliability which is one of important requirement of any application. Transport Protocols like DTSN, M-DTSN, and SHCTAE are good but not enough to guarantee the de sired reliability. It is necessary to do research without excessive utilization of limited resources of WSN so that it will result into an effective system to serve the intended purpose was well as to prolong the network life.

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