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A Survey of Comparison in Classification of Transport Control Protocol for Energy-Efficient Wireless Sensor Network

Samuel Erskine
Computer Science and Engineering
University of Bridgeport
Bridgeport, USA
serskine@bridgeport.edu

Dr. Hassan Bajwa
Computer Science and Engineering
University of Bridgeport
Bridgeport, USA
hbajwa@bridgeport.edu

***Abstract*—In Wireless Sensor Network (WSN), congestion must be tackled with sense of urgency. Due to the fact that there is limited memory, battery and less computational capability. Time sensitive application such as battlefield would require efficient transfer of data in order to maintain energy efficiency state of the sensors. WSN current Transport Control Protocols (WSNCP) have been critically scrutinized, such that integration of major lacking techniques in congestion mitigation would substitute energy efficiency in application deployment of sensors in multihop network environment. Hop-by-Hop and integration of these limited congestion mitigation techniques should be efficient in designing energy efficient sensor network**.

Keywords—WSN, Congestion control, memory, battery, energy-efficiency, TCP, techniques, multi-hop, HBH

I. INTRODUCTION

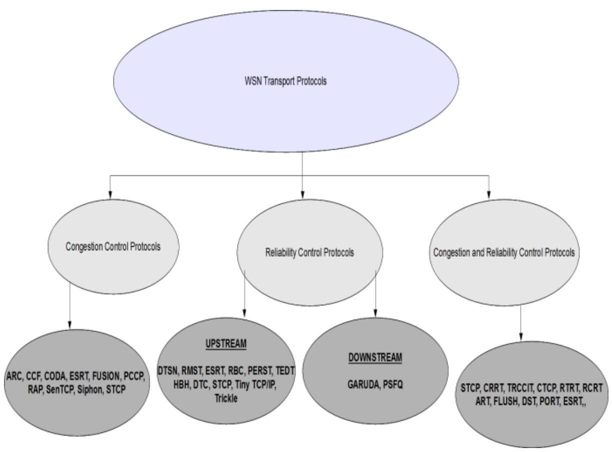
Wireless sensor network (WSN) is required to operate with high power precision. However, low-power operation sensor network has been recognized as critical and undesirable design requirement. With design applications, such as battlefield monitoring, surveillance, and medical field, external source of electrical power would be unavailable. Moreover, with indoor scenario such as machining or structural monitoring, power cables would not be required to be attached to sensor nodes. Usually, with such network, devices can be estimated to exceed over hundreds in a particular sensor deployment. Sensor network devices are required to be undisturbed, which means they would also not require infrastructure support extension, even when it is deployed. Given the promise that the above considerations would not be available, sensor nodes would be required to operate by itself alone, when sources such as batteries energy cells and other forms of applicable energy are not considered. Meanwhile, it would be required that all the energy sources mentioned above would be boundless to the small sensor device. Therefore it would be required that energy efficient design should be potential for prolonged life of the WSN.

Energy-efficiency design challenge in the WSN can be overcome. When this is acceptable the challenges faced at every aspect in the network design can no longer occur. Consequently, there would be no challenges to deal with such as; hardware device, technique, protocols and application. Sensing and data processing in WSN can be assumed as insignificant, based on specific application. This will also have a direct effect with the communication system. Therefore, the system would also become insignificant, when energy consumption is observed in its entirety. Sensor devices could use same energy to communicate information bit amongst them. This would have the intension of executing bulk instruction in the processor in which it is embedded. Based upon this the network communication protocol relate to it behavior and has a uniform distribution, and fairness sharing of resources which would affect the entire sensor system. In addition, this must be designed to sustain energy efficiency. Hence, it is required that transport control protocol of the WSN issues can be assessed based on the technique that would be used in the communication protocol (WSN TCP) description.

A major issue would be required to be addressed in transport protocol for WSNs. This is based on the techniques and protocol description used in this project. The issues account for observation in several techniques in the transport control protocol for the WSN. Congestion mitigation and elimination, and packet loss reduction, which serve a purpose for enhancing fairness share in bandwidth, end-to-end data flow and reliability is required to be investigated. It has also been investigated to know that we cannot relate traditional transport control protocol or internet application, such as TCP or UDP for WSNs [1]. User Datagram Protocol (UDP) was required to possess reliability which would be needed for sensor application. However, UDP does not have any flow control or congestion control. This will usually leads to packet loss which cannot be recovered and hence energy wastage can be observed. TCP is speculated to be the right transport protocol for WSN, but TCP has been identified with many shortcomings: 1) Absence in overhead in the TCP connectivity would be highly recommendable, which would enhance small data gathering in event-driven applications.2) Based on the assumption which our work proposes, it would be appreciable to unite all sensor node as close as possible to the sink, through hop-by-hop introduced technique, so that TCP would uniquely introduce fairness in sharing of bandwidth and data distribution. 3) If TCP extension would adopt hop-by-hop congestion control and hop-by-hop reliability and a hybrid of the two, that has the tendency to provide reliable data, this would be appreciable to larger extent, than TCP relying only on end-to-end retransmission which has the capability of consuming more energy and bandwidth.

Our work bears the responsibility by reviewing the various transport control protocol for the WSN. It identify the existing transport protocol techniques which have not been well accounted for in the literature, and fulfill the design requirements in the WSN TCP. The rest of the work would be summarizing as below:

Fig2. Classification of Current WSN Transport Protocols



II TRANSPORT PROTOCOL DESIGN FOR WSN

The communication protocol stack, illustrate that the transport protocol is situated on top of the network layer protocol. An important emphasis in design of the transport protocol is for a designer to consider both end-to-ends as well as hop-by-hop placement in message transmission. At one point message fragmentation results in segments from the sender, and at the receiver the message becomes reassembled. When we think of effective design, the WSN transport protocol must be efficient in delivering the following functions such as: high order transmissions, flow control support, congestion control support, recovery from loss with high precision, and also considering QoS guaranteeing that can results in time requirements and fairness.

2.1Techniques and Performance Measurement in WSN

It is imperative to introduce techniques and evaluate performance metric in WSN based on design of transport protocol that provides end-to-end reliability, end-to-end QoS and hop-by-hop reliability, hop-by-hop Qos contributing to energy efficiency WSN design. In the WSN, performance evaluation of the transport protocol design may concern metric factors such as: energy- efficiency, QoS provision metrics example of which is high packet loss, reliability, packet latency and jitter delivery, and fairness.

2.12 Energy-Efficiency Model*:* In energy efficiency model of WSN the dynamics of energy consumption is considered to be of prime importance. A model which has of late been used related to this widely concerns the model in [1]. Following this, the limited energy withholding capacity of the wireless sensor nodes must be capable of having in place a transport protocol that has high energy efficiency in mind capable of enhancing the lifetime of the sensor nodes. Resolving packet loss is a must since there is potential increase in congestion and high bit error rate. In application where loss is sensitive to the environments, where packet loss is classified severe, automatic retransmission must occur which incur additional use of energy. Based upon this, amongst several factors that need to be observed in energy efficiency are: control message overheads, retransmissions and the retransmission distance need to be critically observed and evaluated.

2.13 Reliability and Availability: In WSN reliability and availability can be estimated together [2], which can be dependent on approaches such as channel frequency bandwidth, noise relation to signal power. Other forms of reliability that is important can be assessed based on the application dependency. Usually, classifications of reliability such as highlighted above can be assessed on: packet-based reliability, event-based reliability. The reliability of various wireless components is estimated in addition to its availability due to the complexity nature of wireless sensor nodes. In packet based-reliability, packet successfulness transmission is required, depending on the fact that there is evidence in loss-sensitivity. *Events reliability*; in this reliability, event detection becomes a top agenda for the particular wireless sensor application; transmissions successfulness does not count.

2.14 QoS Metrics: In WSN quality of service (QoS) concerns the delay, latency, packet error, loss rate metrics, and jitter, which is aimed at improving the WSN data reliability in order to prolong the lifetime of the sensors network [3]. The application requirements use the metric or its variations which are useful to the particular sensor network situation. A typical application in which the sensor nodes can be useful is when sensors are deployed in the battlefield surveillance. Based upon this application of the WSN, a high data stream requirements is demanded, which also uses more bandwidth as compared to when it is used in the event based.

2.15. Fairness*:* In fairness, the WSN nodes resources are equally divided, with the aim of ensuring that equal bandwidth is distributed so that the sink can easily communicate with each sensor [4] [5]. By fairness sensors are believed to cover entire region of deployment. In WSN the convergent of upstream traffic being many-to-one sensor nodes which are far apart encounter difficulties such that the sink cannot easily transmit data.

2.16 Congestion Avoidance and Mitigation:

In congestion mitigation, packets delay is experienced in forwarding and generation mode, and the network congestion is prevented at the bottleneck. When congestion occurs, also, packet arrival rate exceeds packet service rate. The sensor nodes which are close to the sink have combined effect of upstream traffic, and this is where the above observation of packet arrival rate exceeding the packet service rate effect is experienced. Other causes in congestion can be estimated to be caused as a result of link level performance influence example of which is: contention, interference and bit error.

2.17 Congestion Discovery: Traditional TCP for wired network infer congestion to be discovered at the end of the nodes, which usually occurs as a result of unacknowledged packets or timeouts. WSN network uses more proactive means in discovering congestion. Queue length [6], packet service time [7], or in the intermediate nodes [23, 8] there exist a ratio between packet service time and packet inter-arrival time have been identified as a common mechanism for use.

2.18 Implicit and Explicit Congestion Notification: Immediately congestion is detected, it is the responsibility of the transport protocol to propagate or notify congestion information from all nodes in which congestion has severely observed, which is communicated to the upstream sensor or any other nodes that has helped in identification of congestion. Usually, congestion can be assessed as single binary bit – or known as congestion notification (CN) bit [10], or data rate information rich in nature, which can also apply to congestion degree [11].

Congestion Correction Rate: When a sensor node has received any congestion notification, it is the responsibility of the sensor to issue a correction to its sending rate. In an event when a congestion notification bit becomes severe effect, a scheme or its variation such as – Additive Increase Multiplicative Decrease (AIMD) can be applied to correct the congestion rate. In most cases where applicable for excess availability of congestion information, it is important to apply accuracy correction rate which should be functional to cases such as in [12].

2.20 Arbitrary Loss Recovery

Transmission loss observation in WSN can be clearly seen than in wired links of comparable nature. When losses occur, senders would not be able to receive any acknowledgement [14] given a retransmit timeout, and packets will eventually drop. In the event that a sender is required to retransmit packets, timer is exponentially reduced, and congestion windows are shortened to units. and notification, and considering also retransmission –based loss recovery.

2.21 Loss Detection and Notification

Considering the reliability of the transport protocol for the WSN, all packet loss must be acknowledged and notified by the receiver. These packet loss should not be different It must corresponds to its counterpart data storage mote that comes from retransmission of relevant source which must be determined. In case a packet loss is discovered, packet sequence number mechanism detection should be in place to acknowledge the packet loss. To describe the way packet loss detection and notification happens two fields are embedded in the source with the packet header; which are source identifier and sequence number. When packets are well receipt, it is mandatory for the receiver to check that the sequence number appears correct, otherwise sequence number gap detection, triggers the automatic detection corresponding packet to know the sequence number missing [15].

Packet loss in WSN has been accepted to be more common than counterpart wired network. Based upon that loss detection cannot be easily achieved, and so WSN must be carefully designed to suite a particular type of usage. Again, sequence numbering mechanism can be applied in each packet header. When sequence numbering is carefully consistent, loss detection can easily function correctly. As we have assumed that it should be possible that hop-by-hop and end-to-end reliability should be in a WSN design so should loss detection must be either hop-by-hop or end-to-end. This means it is important that hop-by-hop and end-to-end must be importantly placed in WSN design so that whichever the requirement of the particular WSN application would be needed, it can automatically be adjusted for use. As TCP uses end-to-end approach in loss detection, both sender and the receiver are responsible for loss detection and notification. Hop-by-hop mechanism packet loss detection seems different, in that packets loss occurrence are being notified by intermediate nodes.

As researchers held, they presume end-to-end approach should not be used for WSN design due to the following reasons: 1) TCP ACK control message used in end-to-end loss detection chooses extended path so that latencies may be observed and is not a better choice for energy efficiency; 2) Multiple hops paths in which the control messages chooses, this can be considered as higher probability loss in the WSN as a result of the congestion or higher link error; 3) Loss detection occurrence in end-to-end which eventually leads to end-to-end retransmission in recovering loss. Based on the deductions from the above three analysis, it is evidently clear that more energy will be consumed when only end-to-end is placed in the WSN design as compared to hop-by-hop retransmission design.

packet loss using timer-based or overhearing not; based upon that, packet loss determination would be known.

The receiver-based loss detection uses a different mechanism and packet loss is inferred by receiver and immediately determines out-of-sequence packet arrivals. In order for the sender to be notified of any acknowledgement three methods can be counted: ACK (Acknowledgement), NACK (Negative Acknowledgement), and IACK (Implicit

Acknowledgement). In ACK and NACK special control message is used while in Implicit Acknowledgement (IACK) [31, 16] acknowledgement information in the data packet header is piggybacked. When an overhead packet in IACK avoided is required to be retransmitted, this would mean the packets have higher chance of being acknowledged and received at same time. In IACK, control messages overhead are required to be generally avoided, which leads to more energy-efficiency. This application in IACK of senor nodes would generally be assessed on if it has the capability to overhear physical medium of the transmission.

2.22 Loss Recovery Based-Retransmission

In WSN, loss recovery occurs as a result of packet drops re-establishment when packets retransmission takes place. There are two ways in which loss recovery must be observed: hop-by-hop and end-to-end loss recovery. The hop-by-hop loss recovery uses intermediate sensor nodes for caching purposefully for packets message, which in turn enables it to perform loss detection and notification. In end-to-end loss recovery, reliable data transfer sense information from source to destination nodes.

Loss recovery-based retransmission can either occurs in end-to-end or hop-by-hop based. End-to-end loss recovery-based retransmission depends on the source which actually performs the loss recovery-based retransmission. The hop-by-hop loss recovery-based retransmission uses intermediate nodes, and loss notifications search are determined on local buffer. In the event of loss search determination, when the lost packet is recovered, retransmission will automatically occur. Contrary to that, the loss information would have to be relayed upstream until it reaches the corresponding nodes.

In WSN, all nodes that have packet cached are named cached point while all the nodes where packets is considered lost are named loss point. Number of hops which exist between them can be referred as retransmission distance. In the retransmission distance, it is quite easy to determine retransmission efficiency based on energy consumed on retransmission. When considering the end-to-end retransmission such as the traditional TCP, usually cache points are denoted as the source nodes. The hop-by-hop retransmission cache point can be denoted by its predecessor node as the loss point .It can be estimated that end-to-end retransmission has longer retransmission distance, however, hop-by-hop retransmission is perceived to be more energy efficient. However, in hop-by-hop loss recovery, it is impossible to assure message delivery in case of node failure, except local rerouting can be permitted. The end-to-end gives way for application-dependent variable reliability, which has a typical case in ESRT. Comparatively, it can be estimated that the hop-by-hop lost recovery averagely does well in case it is determined that 100% packet reliability must be maintained, meanwhile, in some cases of WSN application, typical example would be event-driven cases, there would not be need for sensor node requiring 100% reliability.

certain time duration estimated much longer than the RTT. In hop-by-hop loss detection and retransmission, a different situation occurs in which influence of cache duration occur is as a result of the summation of local packet service time and a hop packet retransmission time.

Priority importance attachment in hop-by-hop retransmission in WSN design is far desired; its related issues and dealings must be discussed. First priority is to consider when should retransmission be triggered? We aim to design a retransmission in WSN such that it must use automatic triggering, in an event when packet loss is immediately felt. By this action, it would consequently cause only short delays as it is a requirement for time sensitive applications. It is important to take a notice about a situation where packet loss issue can complicate as a result of congestion; congestion could critically be impair resulting in more packet loss. Another issue worth knowing is about cache point. There is a concern about where packets transmitted should be cached. Hop-by-hop retransmissions cache each packet at intermediate sensor node. When sensor nodes only possess a limited memory, it is necessary that packets must be cached at only few chosen nodes. One main issue that remains to be resolved is the way to distribute cached packets in the midst of all nodes set. A typical solution known as Distributed TCP Cache (DTC) [17] has the tendency to resolve buffer constraints issues and also increase retransmission efficiency when they resort to using probability-based cache selection points.

III **CURRENT WSN TRANSPORT CONTROL PROTOCOL**

3.0 Congestion Control and Enhancement

Congestion control in WSN have actually benefited from upstream traffic direction flow. Congestion control such as: ECODA [34], PHTCCP [46], FUSION [44], ARC [39], CODA [30], Trickle [43], SIPHON [48], PCCP [31], and CCF [29] have been well accounted for in identifying new congestion mitigation techniques that would enable efficient design for energy efficiency in WSN.

Table I **Comparison in Congestion Control Protocols for WSN**

FEATURE / PROTOCOL	CONGESTION DISCOVERY (CD)	IMPLICIT CONGESTION NOTIFICATION (ICN)	EXPLICIT CONGESTION NOTIFICATION (ECN)	CONGESTION AVOIDANCE (CA)	RELIABILITY DIRECTION (RD)	LOSS RECOVERY (LR)	LOSS DETECTION & NOTIFICATION (LDN)	ENERGY EFFICEINCY (EE)	RELIABILIT PRESENCE (
ECODA	QUEUING & PACKET CONDITION	NO	YES	RATE-ADJUSTMENT ENHANCED-PACKET DROP	UPSTREAM	--	ACK	GOOD	PACKET-SELECTION
PHTCCP	PACKET-SERVICERATIO	YES	NO	RATE-ADJUSTMENT	--	--	--	--	PACKET
FUSION	QUEUE-OCCUPANCY CHANNEL-SAMPLING	YES	NO	PRIORITORIZED-ACCESS LOCATION	--	H-B-H	--	NONE	--
ARC	QUEUE-OCCUPANCY	IMPLICIT	NO	RATE-ADJUSTMENT FUNCTION	--	--	--	--	--
FACC	PACKET DROP-RATE AT THE SINK	NO	YES	RATE-ADJUSTMENT	--	H-B-H	--	--	PACKET
CODA	BUFFER-OCCUPANCY, CHANNEL-LOAD	NO	YES	RATE-ADJUSTMENT	--	--	ACK	GOOD	PACKET
TRCKLE	--	NO	NO	POLITE GOSIP	DOWNSTREAM	H-B-H	--	--	--
SIPHON	APPLICATION-FIDELITY	NO	NO	TRAFFIC-REDIRECTION OPERATING-SCOPE CONTROL	--	H-B-H, E-T-E	--	NONE	PACKET
PCCP	PACKET-INTERVAL DURATION PACKET-SERVICE DURATION	NO	NO	WEIGHTED-FAIRNESS	--	--	--	ENERGY	--
CCF	QUEUE-OCCUPANCY PACKET FLOW	YES	NO	RATE-ADJUSTMENT	--	--	--	ENERGY	--

Table II **Comparison in Reliability & Congestion Control Protocols for WSN**

FEATURES / PROTOCOL	CONGESTION DISCOVERY(CD)	IMPLICIT CONGESTION NOTIFICATION (ICN)	EXPLICIT CONGESTION NOTIFICATION (ECN)	CONGESTION AVOIDANCE (CA)	RELIABILITY DIRECTION (RD)	LOSS RECOVERY (LR)	LOSS DETECTION & NOTIFICATION (LDN)	ENERGY EFFICIENCY (EE)	RELIABILITY PRESENCE (RP)
RCRT [36, 37]	QUEUING PACKET LOSS RATE	YES	NO	RATE-ADJUSTMENT	UPSTREAM	E-T-E H-B-H	NACK, MAC	NONE	PACKET
TRCCIT [17]	PACKET LOSS RATE	YES	NO	RATE-ADJUSTMENT	UPSTREAM	H-B-H	IACK, ACK	NONE	PACKET
PCCP [31]	QUEUING TRANSMISSION LOSS	NO	YES	RATE-ADJUSTMENT	UPSTREAM	H-B-H	ACK DOUBLE ACK	NONE	PACKET
RCRT [36, 37]	LOSS RECOVERY TIME	YES	NO	RATE-ADJUSTMENT	UPSTREAM	E-T-E	NACK	NONE	PACKET-ORDER
STCP [21]	QUEUING	YES	NO	RATE-ADJUSTMENT TRAFFIC-REDIRECTION	UPSTREAM	E-T-E	ACK, NACK	GOOD	DATA STREAM, PACKET
ART [26, 27]	SEQUENCE NUMBER LOSS DETECTION	YES	NO	RATE-ADJUSTMENT	UPSTREAM DOWNSTREAM	E-T-E	ASYMETRIC ACK NACK	GOOD	PACKET
FLUSH[38]	SEQUENCE NUMBER LOSS	YES	NO	FLOW RATE-ADJUSTMENT	UPSTREAM	H-B-H E-T-E	SELECTIVE NACK	NONE	PACKET
DST [33]	DELAYED PACKET NUMBER SEQUENCE NUMBER LOSS	YES	NO	RATE-ADJUSTMENT	UPSTREAM	E-T-E	--	NONE	PACKET
PORT [40]	NODE-COMMUNICATION COST	YES	NO	RATE-ADJUSTMENT	UPSTREAM	E-T-E	--	NONE	PACKET
ESRT [22]	GROUP LOSS DETECTION	YES	NO	RATE-ADJUSTMENT	UPSTREAM	--	--	ENERGY	EVENT

Table III **Comparison in Reliability Protocol for WSN**

FEATURES / PROTOCOLS	CONGESTION DISCOVERY (CD)	IMPLICIT CONGESTION NOTIFICATION (ICN)	EXPLICIT CONGESTION NOTIFICATION (ECN)	CONGESTION AVOIDANCE (CA)	RELIABILITY DIRECTION (RD)	LOSS RECOVERY (LR)	LOSS DETECTION & NOTIFICATION (LDN)	ENERGY EFFICEINCY (EE)	RELIABILITY PRESENCE (RP
DTSN	--	--	--	ARQ,	UPSTREAM	E-T-E CACHING H-B-H	ACK, NACK, MAC	NONE	PACKET
RMST	--	--	--	ARQ	UPSTREAM	H-B-H E-T-E	NACK, MAC	GOOD	PACKET
PSFQ	--	--	--	REFETCH OPERATION	DOWNTREAM	H-B-H E-T-E	NACK	GOOD	PACKET
DTC	--	--	--	AIMD	UPSTREAM	H-B-H	ACK, SACK	GOOD	PACKET
GARUDA	--	--	--	--	DOWNSTREAM UPSTREAM	OUT OF ORDER LOSS RECOVERY	NACK	NONE	WAIT FOR FIRS PACKET
ERTP	--	--	--	--	UPSTREAM	H-B-H	IACK, ACK	GOOD	PACKET
TEDT	--	--	--	--	UPSTREAM	H-B-H	IACK	NONE	PACKET
DTPA	--	--	--	FIXED SIZE WINDOW BASED	UPSTREAM	E-T-E	ACK, SACK, NACK	NONE	DATA PACKET
ESRT	--	--	--	RATE ADAPTABILITY	DOWNSTREAM	--	IACK	ENERGY	SENSOR DATA PACKET
RBC	--	--	--	--	UPSTREAM	H-B-H	ACK	NONE	PACKET
EERT	--	--	--	CRC	UPSTREAM	CODING	IACK, NACK	ENERGY	DATA PACKET

3.1 Reliability and Congestion Control

One WSN transport control protocol STCP has upstream flow direction and uses end-to-end reliability and congestion control. A new technique that is identified would be Implicit Congestion Notification (ICN), and Explicit Congestion Notification (ECN). Many other techniques that refer to ART, and DST are packet loss detection and unique sequence are also new congestion mitigation techniques which should be capable of enhancing new design in the WSN.

Reliability protocols for the WSN have reliability features like reliable presence, direction and instant loss discovery and notification which are very important for energy efficiency and congestion control. Now, new congestion discovery techniques such as Automatic Request Transmission (ARQT) in DTSN and re-fetch operation in PSFQ would also be ideal in describing a new design in the WSN TCP.

IV. **Issues to Be Considered and Design Guidelines in WSN**

Design guidelines for an efficient transport protocol in WSN can be observed as follow: the topology, diverse application, traffic, and resources constraints in WSNs. Amongst these design guidelines and constraints, two or more important design guidelines and constraints are energy efficient design constraints and fairness which must be assessed based on environmental and geographical placements of sensor nodes. Unique and high energy-efficiency coupled with flexibility, reliability, and QoS characteristics such as latency, jitter, delays must be given a higher priority resulting in higher throughputs, packets loss rate, end-to-end and hop-by-hop delay.

The analysis given above indicates that a different category of transport protocol would be needed in WSN design. Because of limited transmission capability in air transaction by which the sensor network transfer data. Based upon that WSN must provide a complete coverage to overcome congestion. Sensor network must also enhance diligent loss recovery, as compared to traditional transport control protocol (TCP) in wired network which uses a physical medium such as copper, fiber etc. in transferring data overcome congestion. Sensor network must also enhance diligent loss recovery, as compared to traditional transport control protocol (TCP) in wired network which uses a physical medium such as copper, fiber etc. in transferring data. These two important design component directly associates with energy efficiency, availability, flexibility, reliability, and all the QoS applications mentioned previously (i.e. latency, jitter, delays etc.). In order to perform these tasks efficiently, generally two approaches must be followed:

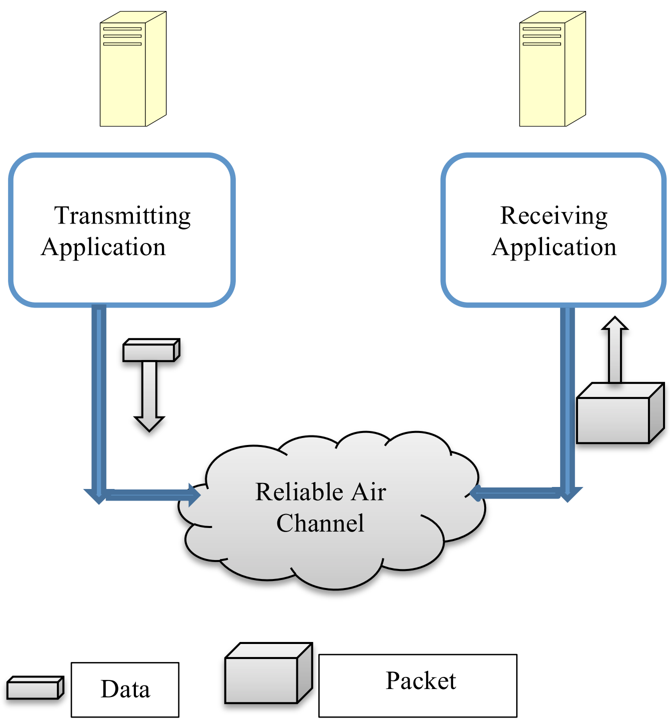


Fig.2 Reliable data transfer from Sensor Nodes

V. **Research Concerns**

Wireless sensor network transport control protocol can be categorized with main objectives of achieving full congestion control, reliability certainty, and energy efficiency. By realizing full potential capability in congestion control and reliability affirmation other objectives of the WSN can be possible. From the conclusion of the study of the literature, existing transport control protocols for the WSN have only concentrated in congestion control and reliability. This is possible as a result of using the description of upstream and downstream reliability direction. Based on investigation completed, conclusion in Tables 1, 2, &3 have been drawn on congestion control protocols, and reliability protocol. Based upon this, there has not been any of the existing transport control protocol in the literature which has been identified concurrently to consider hop-by-hop reliability, end-to-end reliability, as well as hop-by-hop congestion control, end-to-end congestion control as complete reliability direction in upstream and downstream flow.

Multihop forwarding and reliability in WSN should include hop-by-hop reliability, hop-by-hop congestion control, and end-to-end reliability in data exchange technique. With these conditions satisfied, it would be possible to deal with harsh environmental conditions of sensor deployment. Usually in such conditions, packet loss and packet reordering are more important to consider. This leads to a decrease in hop-reach agreement and reliability in the WSN channel packet error rate and data exchange that would be required to undertake. Meanwhile, the network size comprising of the number of sensor nodes hop-reach agreement and reliability is such important that it depends on the success rate at which the sensor nodes must reorganize themselves appropriately. This can be done more appropriately by considering a better approach in which topology and fairness sharing in bandwidth can be addressed. This has direct consequence with optimal placement of sensor nodes which corresponds to smooth transfer of data and energy efficiency in the sensor network. Topology control and bandwidth adaptation work together in sensor network. Based upon this sensor nodes reorganize themselves more appropriately to achieve efficient energy transfer. A transport control protocol that will satisfy these requirements in literature for the WSN has been underestimated. In addition, there have not been detail accounts in such transport control protocol techniques in the literature that account for energy efficiency and fairness sharing in the bandwidth. Meanwhile, WSN applications such as battlefield monitoring, surveillance, and medical application has been classified as time-sensitive, which demands equal sharing in bandwidth. Therefore, it is imperative that disparity transport control protocols and techniques must be critically examined, and lacking protocols in the literature must be integrated into the existing congestion control, and reliability protocols (Tables 1, 2 and 3). These would have to be reconsidered in the design for new and energy efficient transport control protocol for WSN.

Subsequently, congestion control protocols such as FUSION, CODA and ECODA etc. are timely. This has been investigated and decision has been reached that would satisfy the requirement of good transport control protocol. FUSION considers that queue sampling and channel coding (Table 1) are new congestion discovery technique that can enhance hop-by-hop reliability and hop-by-hop congestion control. Whilst CODA and ECODA would be a new hybrid that would together considers buffer occupancy and channel coding as new congestion discovery technique in the literature. This presupposes that further enhancement in loss detection and notification will provide energy efficiency for the WSN. SIPHON is also another important congestion control protocol that has discovered new congestion discovery technique such as application discovery that will enhance both hop-to-hop reliability and end-to-end reliability, and hop-by-hop congestion control and end-to-end congestion control. In that case the system should readjust itself and becomes adaptable to all time-sensitive application and all other sensor application including non-time sensitive

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