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Wireless Sensor and Actuator Networks (WSANs): Insights and Scope of Research

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Abstract**: *Recent years are witnessing the growth of different kinds of networks including Wireless Sensor and Actuator Networks (WSANs). WSANs are self-configured and ad-hoc natured networks without any permanent infrastructure that consists of numerous sensor nodes and few actuator nodes that can collaboratively monitor the characteristics of physical and environmental conditions like vibration, sound, temperature, pressure, motion or pollutants, and determine an appropriate action to take depending upon the sensed data, thereby changing the state of the field of interest by performing the suitable action in it. We can say it as an advancement of Wireless Sensor Networks (WSNs) with the inclusion of actuating component. Along with the existing research challenges of WSNs, the WSANs have many additional research challenges to be addressed. This paper gives an insight into the scope of ongoing and future research in the aspect of preserving temporal relationship among the events, restoring the connectivity in case of node failures, need for QoS parameters, along with several operational details of WSANs.***

Index Terms**: Actuator, Clustering, Connectivity restoration, QoS, Sensor, Wireless Sensor and Actuator Networks.**

I. INTRODUCTION

WSNs are used in battlefield monitoring, security surveillance, health monitoring systems, physical environment monitoring, military applications etc. These are the composition of a large number of wireless sensor nodes which have limited sensing capacity, processing and transmitting (radio) capabilities [1]. In contemporary years WSANs are gaining a lot of prominence with rapid growth due to their diversified applications in several fields of interest. WSANs consists of numerous passive sensors similar to the WSNs to sense the event area for some physical phenomenon and in addition they also contain few actuators to perform a suitable and reliable action in the event area depending upon the sensed data. Earlier in WSNs there was no component for performing any action based on the sensed data, hence the WSNs were used only for sensing the field, but WSANs are added with an additional component called an Actuator. Therefore WSANs are able to take immediate and necessary action in the event area depending upon the sensed data. Actuator node usually is extra powerful than a normal sensor node with respect to energy, storage capability, computation capability, and transmission range.

A WSAN is typically meant for a particular task completion, and for a particular application, but in several setups it is being used as a general application for the communication infrastructure. The ubiquity of WSAN and its integration with the Internet of Things (IoT) started to rise with the minimization of WSAN hardware cost and the large availability of the effective infrastructure of Internet.

WSANs are witnessing myriad successful applications, from the field of agriculture to industries, Cyber-Physical Systems (CPS), Protection of Critical Infrastructure, Smart Cities and Self-sufficient Animal Control. Contrariwise, a rising potential with respect to research and development in WSANs is still mostly untapped [2] [3] [4]. While current WSANs are constrained with the actuation capability, and also constrained on the abilities for reasoning and sensing, the future WSANs are going to have even more powerful and heterogeneous nodes with powerful actuators, and are likely to be deployed on very large fields of interest. To extract the benefit of the capability of actuator nodes, there is a requirement of an effective communication/cooperation. Commonly, we can identify from the literature coordination of three levels, viz. sensor-to-sensor coordination (S2S), sensor-to-actuator coordination (S2A) and actuator-to-actuator coordination (A2A). The S2S coordination is required to collect data from the targeted field of surveillance. Then, the S2A coordination is performed to transmit gathered data from the sensor to a particular actuator. Lastly, the A2A coordination is required to perform the suitable and reliable act by negotiating with the remaining actuators [5]. Hence, we can say that the WSAN comprises three significant operations, viz. the sensing the events, making the decision, and acting in the area where the even has been occurred. Fig. 1 depicts the basic architecture along with the main components of WSAN.

The works presented in this paper are being congregated from related and focused journals, proceedings of workshops, and conferences. This study is not intended to project comprehensive view of the WSANs, as the speed at which developments are emerging is fairly amazing, but, we intended to provide summary of illustrative studies contributing several viewpoints on the research scope of different aspects of WSANs. The remaining paper is organized as given here. Section 2 will fleetingly focus on the fundamentals of Sensors and their technology, along with the diagrammatical explanation of a sensor node. The necessity and the process of electing a Cluster Head (CH) is described in Section 3. Further, section 4 summarizes the coordination and routing mechanisms in WSANs with the help of a pictorial classification of different types of routing protocols. Section 5 gives a glimpse of importance of connectivity restoration in case of node failures. The need for preserving temporal relationships of the events along with the advancements

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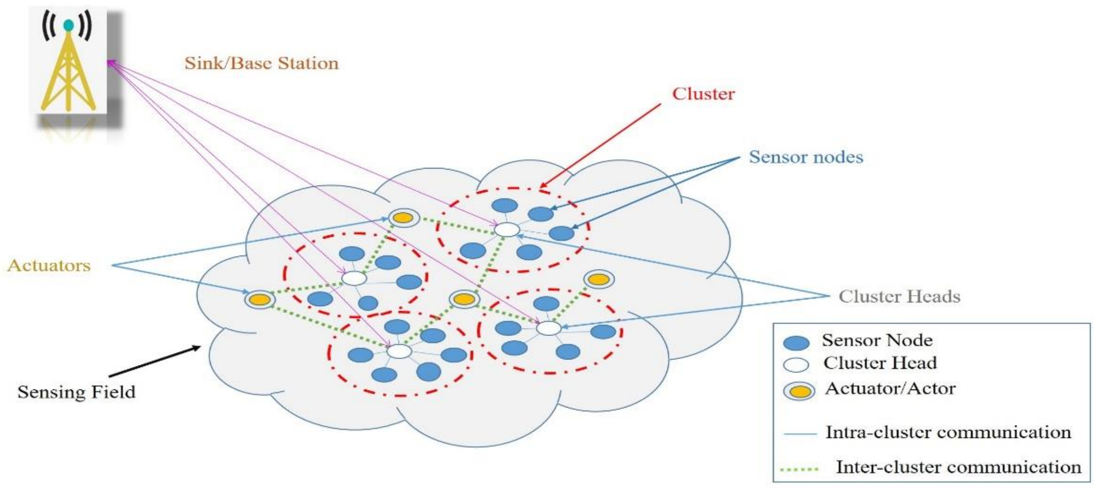

Fig. 1. Basic architecture of a WSAN

that are done so far are presented in Section 6. Section 7 describes QoS along with listing out the main parameters that affect QOS. Finally, Section 8 concludes our work briefing the summary of the aspects of WSAN and mentions the open research problems.

II. FUNDAMENTALS OF SENSORS AND THEIR TECHNOLOGY

Typically a normal sensor node is embedded with the processing abilities and on-board storage; a node can contain multiple sensors operating in seismic, infrared, optical, radio (radar), chemical, magnetic, acoustic, and biological fields. The node contains the interfaces for communication, usually wireless links, to connect to the neighbouring fields. In addition, a sensor node usually has knowledge of its location and positioning which is attained using a Global Positioning System (GPS) or by using a local positioning algorithm [6]. Every sensor node that is distributed, is capable to collect the data, analyse the collected data, and route the analysed or aggregated data to an allotted sink point. Sensor node mainly contains the sensing unit, the processing unit, transceiver, and the power unit. Typical structure of the sensor node is depicted in Fig. 2.

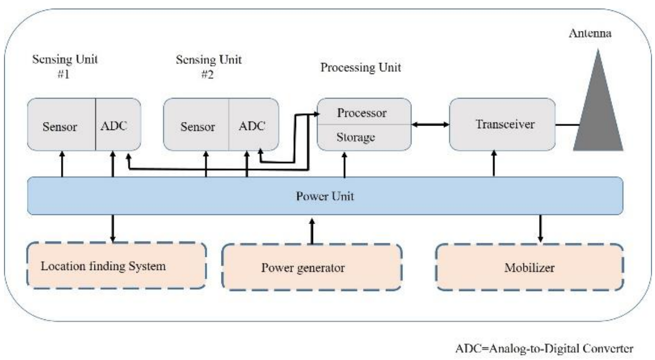

Fig. 2. Structure of a Sensor node

Every physical phenomenon in nature is available and can be captured in the form of an analog signal, hence, that needs to be converted into digital signal in order to be processed by the electronic circuit. Therefore Analog to Digital Converter (ADC) is required for this purpose. On the other hand, the actuator node also contains similar components as a sensor node with a replacement of ADC with DAC, and a sensor with an actuator. The Sink node is a special kind of node to which the remaining sensor nodes send the data collected for further processing. There can be TWO types of WSANs depending upon whether the sink node is involved in the decision making or not, namely an automated and semi-automated networks. If the actuator nodes are able to take the decision among themselves without the involvement of sink node, such network is called as an automated network, and if the decision making regarding the action to be taken is performed by the sink node, it is called as a semi-automated network. Once the sensor nodes are deployed in the event area, they will form into clusters according to some criteria. Cluster formation is required in order to avoid the necessity for every node to communicate with the sink/actuator to send its data which leads to the wastage of energy, thereby decreasing the life time of the entire network. Instead, each cluster can elect a node that acts as a CH whose duty is to communicate with the sink/actuator node.

III. CLUSTER HEAD ELECTION

Ordering the nodes into multiple clusters is broadly accepted by the researchers to achieve the scalability goal and higher energy efficiency to have prolonged network lifetime [7]. A CH is responsible to collect the sensed data from various member nodes of same cluster and then forwarding it to a nearest actuator/sink. The nodes once deployed in the event area will form into multiple clusters and elect a CH depending on some criteria [8]. Usually, nodes which have the highest energy level are chosen as the CHs as they are responsible to process the data collected and to communicate with the actuator.

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The main scope of research with respect to sensor nodes is to develop algorithms for their effective communication with other nodes and with the sink that consume less energy, thereby increasing lifetime of the entire network. CH has to involve more in processing and transferring the data than a normal sensor node, as a result it loses its energy quickly, and hence needs a lot of energy. The current energy available in a node is termed as residual energy, and every node drops some amount of energy for both of its operations i.e., for sending the data and receiving the data. Usually the optimal set of CHs among all the nodes is formed considering the residual energy of a particular node. The normalized residual energy of a node is calculated as below:

$$P_i = \frac{re_j}{\sum_{j \in n(i)} re_j} \qquad (1)$$

Where

re_j = residual energy of node j

n(i) = set of neighboring nodes of i

P_i = the normalized preference of node i

previous 1/p rounds

T(sn) = the threshold value of the node sn

If n < T(n), the node turns to be a CH. Few algorithms take into consideration the energy which is currently available in the node, in order to decide the CH, and such algorithms are called as deterministic threshold algorithms which are depending upon the below formula [11].

$$T(n) = \frac{p}{(1-p) * (r \bmod p^{-1})} \frac{E_{n-current}}{E_{n-max}} \qquad (3)$$

Where

$E_{n-current}$ = The amount of current energy

E_{n-max} = The initial energy

To improve the energy saving the above formula is modified to include whether or not that node was recently elected as a CH, thereby ensuring that each node gets an opportunity to become a CH and eventually achieving the load balancing in the network.

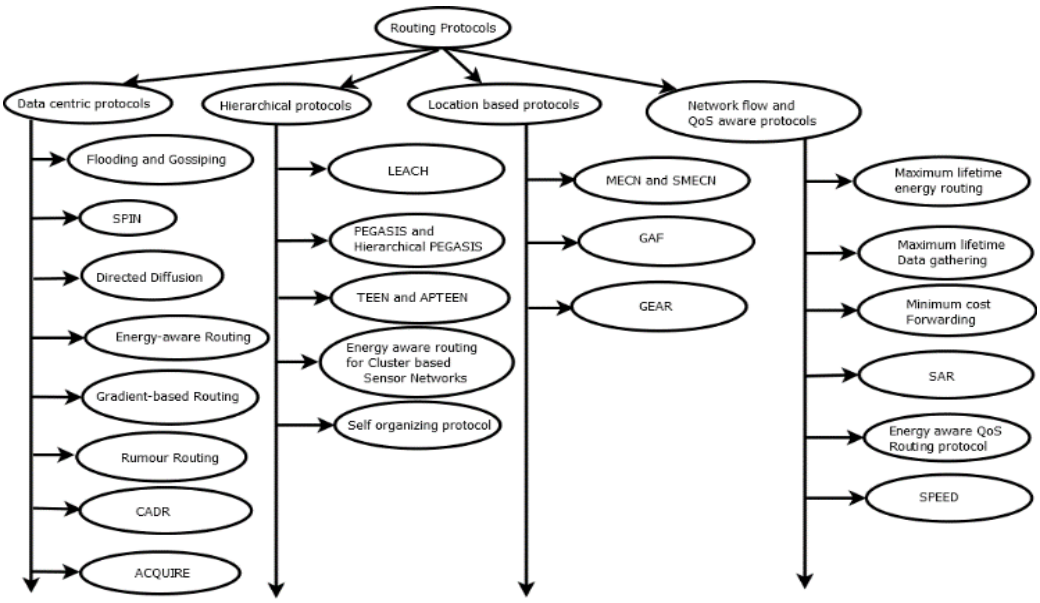

Fig.3. Classification of routing protocols

Few algorithms choose the CHs stochastically using the formula given below [9] [10]. For selecting a CH, each node *n* defines one random number which lies in between 0 and 1. When compared *n* with the threshold value T(n), if it is less, then the node becomes the CH for the current round. Usually, the threshold value is set as follows:

$$T(sn) = \begin{cases} \frac{p}{(1-p)*(r \bmod p^{-1})} & \forall sn \in G \\ 0, & \forall sn \notin G \end{cases} \qquad (2)$$

Where

P = cluster head probability

G = set of nodes that were not chosen as CHs during the

$$T(n)_{new} = \frac{p}{1-P*(r \bmod P^{-1})}\left[\frac{E_{n-current}}{E_{n-max}} + \left(r \operatorname{div} \frac{1}{p}\right)\left(1 - \frac{E_{n-current}}{E_{n-max}}\right)\right]$$

(4)

Where

r = number of consequent round of a node in which it was not a CH.

Most of the existing algorithms for CH election are based on the above stated formulae (2), (3), and (4). Once the clusters have been formed, and the CHs have been elected, the nodes have to communicate among themselves in order to coordinate and share the sensed data and to perform data aggregation at the sink or at the actuator.

Data aggregation is the procedure of combining the sensed data from several sensors

IV. COMMUNICATION AND ROUTING MECHANISM IN WSANs

Communication is needed in WSANs in order to achieve coordination among the nodes and to have routing mechanism as well. WSANs need effective communication/coordination between the nodes and the actuators as well. The communication among the nodes is mainly required to achieve the coordination among them.

A. Sensor- to-Sensor coordination (S2S)

This coordination leads to share the sensed data among the neighbouring sensors, and also to use a sensor as a relay node in the process of forwarding the sensed data either to a particular sink or an actuator [12].

B. Sensor-to-Actor coordination (S2A)

It deals with sending the features of the occurred events from sensor to an actor. Sensor and actor also coordinate for sensor placement or improving connectivity etc. The communication between sensor and actor necessitates energy efficiency to increase the network lifetime. In some real-time applications, like, detection of fire accidents, battlefield surveillance etc. the communication traffic is naturally a delay-sensitive.

C. Actor- to-Actor coordination (A2A)

After the event is sensed, and sensors have sent the data to the actors, the actors need to coordinate among themselves to rebuild it, in order to analyse its characteristics, and to take a collaborative decision finalizing how to act in the filed [13].
Routing mechanism is one of the critical aspects in WSANs in which delay must be considered as an important parameter because the nodes have limited energy, and hence they are prone to get dried up at any time. There is much scope for the research in routing protocols though advancements are being done. Performance of any routing protocol in WSNs and WSANs depends solely on the architectural model of a network. Works presented in [14] classified different kinds of routing protocols as Data-centric, Hierarchical, Location-based, and, Network flow and QoS-aware. There are various protocols under each category of these routing protocols as shown in fig. 3.

NOMENCLATURE OF FIG. 3:

D. SPIN

It is Sensor Protocol for Information via Negotiation. It makes use of three kinds of messages, Advertisement (ADV), Request (REQ) and DATA. Node which has some sensed data broadcasts the ADV message. Usually, this particular message sent by the advertising node will notify the type of data that the node is containing. Then, the nodes that are interested and also received the ADV message forward REQ message requesting that data. The advertised node which has the data collected, will send that data to the nodes which have sent the REQ message. Further, the nodes after receiving the requested data will send ADV message to other nodes, and this process will continue.

E. CADR

It is Constrained Anisotropic Diffusion Routing. In this method, the core act will be to send the query to the sensor nodes and then to route the gathered data in a network for increasing the amount of information gain, while reducing the latency and bandwidth. It can be attained by triggering the sensors which are only in close proximity to the specific event occurred and also by adjusting the routes dynamically.

F. *ACQUIRE*

In ACtive QUery forwarding In sensoR nEtworks, a query is furthered by a base station and every node which receives that query, attempts to reply in part with the help of its pre-cached data and sends it to other sensor nodes. Nevertheless the pre-cached data is not latest, then the nodes will collect the data from all of their neighbour nodes within a look-ahead of *d* number of hops. Once the query has been resolved fully, then it will be returned to the base station through either the reverse path or any other shortest-path.

G. *LEACH*

Low Energy Adaptive Clustering Hierarchy is a hierarchical protocol in which the sensor nodes transmit the collected data to CHs, and the CHs perform the aggregation and compression of the received data, and then forward the aggregated and compressed data to the sink/base station. Every node makes use of a stochastic algorithm in every round in order to decide whether it can become a CH in that round.

H. PEGASIS

It is Power-Efficient GAthering in Sensor Information Systems. It is an improvement to the LEACH protocol and it is a chain based hierarchical protocol. The sensor nodes are formed as a chain for transferring and aggregation of the sensed data. Last node of the chain should be the Sink node, and the node before the sink acts as a leader. Usually the PEGASIS is not suitable for the networks with dynamic topological structure.

I. TEEN

It is a Threshold sensitive Energy Efficient sensor Network which is also a hierarchical protocol especially intended to be responsive towards the unexpected variations in the characteristics of the sensed data. It comprises both the data-centric and hierarchical mechanism.

J. APTEEN

This Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network is an advancement to TEEN protocol. It does both periodic sensing and it is reactive to time critical events but it is different from TEEN as it has to send data if the node did not send it for a count time equal to cluster head. Comparatively it guzzles less energy than the LEACH.

K. MECN

It is Minimum Energy Communication Network that uses the low power GPS. It focuses on finding out the sub-network that has less count of nodes, also it consumes minimal power in transmission of data between any two specific sensor nodes.

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L. SMECN

Stands for Small Minimum Energy Communication Network. It aims at finding out the sub-network with lesser number of edges. It consumes less energy than MECN and the maintenance cost of the links is also reasonably less.

M. GAF

It is Geographic Adaptive Fidelity protocol which is an energy-aware and location-based protocol for routing designed mainly for MANET (Mobile Ad-hoc NETwork), however it is also appropriate for WSNs. This protocol switches off the unused sensor nodes to save the energy without disturbing routing fidelity of the network.

N. GEAR

It is known as Geographic and Energy Aware Routing. It consumes less energy and uses geographically informed neighbour selection heuristics in order to send the data to specific area of the target. Instead of sending the interests to entire network this protocol limits the count of interests in Directed Diffusion by taking into consideration only a particular part of the network.

O. SAR

It is Sequential Assignment Routing which is a primary protocol which includes QoS concepts in routing decisions. It is a table-driven and a multi-path approach determined to attain energy efficiency and fault tolerance. It keeps multiple paths from nodes to the base station. It has the drawback of maintaining at each node, the states and tables.

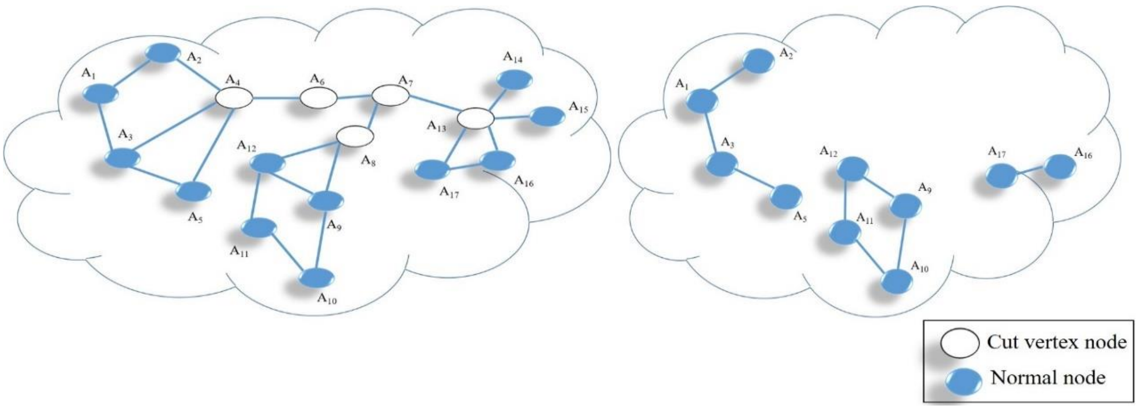
P. SPEED

It is the acronym for Stateless Protocol for End to End Delay. It is a routing protocol with QoS concept which provides the features of soft-real time and end-to-end guarantees. The mechanism of beacon exchange gathers details regarding the nodes and location of those nodes. Then at every node the delay estimation is obtained by calculating the elapsed time when an ACK has been received from a neighbour in response to the data packet transmitted.

Data aggregation should also be taken into consideration while designing a routing protocol for WSANs, as it is one of the important aspects of routing protocols with respect to energy saving, and also the traffic optimization. Hence, novel algorithms for routing are required to tackle the problem of mobility and to tackle the changes in network topology in certain limited-energy environments [14]. As far as the network is connected and sensor nodes are alive the communication among the nodes can be achieved through these routing protocols. The sensor nodes are prone to die because of multiple reasons viz., the deployed fields are harsh and unmanned, and also due to power drain of the sensors and actors.

V. CONNECTIVITY RESTORATION IN CASE OF NODE FAILURE

Connectivity restoration is needed to re-attain the connected network in case of any node failures. Being the reason, sensor nodes are deployed in harsh target fields, chances of failure of sensor nodes are higher. In addition, sensor nodes and actor nodes can also be dead as they have limited energy levels. Therefore the WSANs should have some means for restoring the connectivity in case of node failures. If the node is a leaf node then its failure does not affect the network operation much, but if that sensor node is a cut vertex node, eventually its failure divides the network into multiple subgraphs as shown in the fig. 4. Fig. 4 (a) identifies the cut vertex nodes in the connected graph of the network. If the Cut vertex nodes A4, A6, A7, A8, and A13 are failed then it partitions the entire connected network into several disjoint subgraphs as presented in fig. 4 (b). Hence the effective connectivity restoration policies are necessary to overcome this issue. In [15], they have come up with a Localized motion-based connectivity restoration for WSANs in which they present DCR, a new Distributed partitioning detection and Connectivity Restoration (DCR) algorithm. The first work to deal multiple simultaneous failures of nodes in case of WSN was proposed in [16]. The authors of this work deploy added relay nodes (RNs) in order to re-establish the network connectivity while using less number of Relay Node count. Their work depends on reconfiguration of the topology that is existing instead of engaging extra nodes.



(a) (b)

Fig.4 (a). Connectivity graph and Cut vertex nodes (b) Disjoint subgraph after failure of Cut vertex nodes

This algorithm identifies the critical actors beforehand depending on localized information, also entitles them as backup actors. DCR uses precise node relocation in order to reorganize the network structure and also to regain stronger connectivity which was there before connectivity failure. To deal with numerous simultaneous critical actors' failure, they developed Recovery Algorithm for Multiple failures (RAM). This algorithm deals with failure situations in which there is a concurrent failure of two adjacent nodes. Similar to DCR, even RAM is a distributed hybrid approach which recognizes critical actors and also assigns backup actors to them. But, RAM allocates separate backups to every one of the critical actors. DCR as well as RAM function somewhat diverse objects and don't follow precisely the similar practise for the backup designation and also for the failure recovery. Decision of which algorithm to use depends highly on the necessities of the application. In [17] they proposed one more algorithm by name Least-Movement Topology Repair (LeMoToR) to restore the lost connectivity in WSANs with least movement of the nodes. Works of [18] proposed a simple Hybrid Connectivity Restoration (HCR) in WSANs that combines proactive selection as well as reactive motion. The actor choses a node for backup using its one-hop neighbour table and notifies the backup node in order to administer its stage. If at all the node fails, the chosen backup node will move to the appropriate position to re-establish the connectivity of that particular failed node's neighbours in a reactive manner. This procedure leads to the process of recovery at the backup node and this procedure is repeated till the connectivity restoration of the network is achieved. To minimize the distance travelled, this algorithm chooses the backup node that results in moving the least distance for restoration of the connectivity. Further, this algorithm determines to decrease the total count of communication messages just by sending the information of node failure only to its own chosen backup node. Fig. 5 depicts the process of cascading node motion for restoring the connectivity in case of a cut vertex failure by moving its backup node to the actual position of the failed node. Node A3 is failed therefore the node A4 is chosen as the backup node in fig. 5 (a). Therefore node A4 moves to A4' in fig. 5 (b), and node A6 will move to A6' and finally the connectivity is restored in fig. 5 (c). Basically, HCR is applicable to different types of network topologies, either it is a sparse network or a dense network, and the performance of this algorithm persists stable even if the structure of the network is varied. Abbasi A A. et al., in [19] again tackled the problem of recovering the connectivity by a Least-Disruptive topology Repair (LeDiR) algorithm. In order to create a recovery plan, mostly it depends on the local view of a sensor node regarding the network, by means of which it relocates the minimal number of nodes and guarantees that no path is extended among any pair of the nodes. However, this algorithm is able to handle only a single-node failure at a particular time; and it can also deal with consecutive node failures. This should be enhanced to handle the failures of multiple nodes at the same time by means of including yet another restriction which says no two nodes should share the same node which is chosen as a backup node. As far as this research work is considered they dealt only with two dimensional network, but ample scope is there for the research in three dimensional networks also, and also the coverage parameter of the network is not considered. If the network is connected without any failure of cut vertex node then that network can work towards fulfilling its objectives. When the sensors are sending the data sensed, there is a possibility of some changes in the order of the data arrival at the sink/actor due to the delay in transmission or the network traffic. To take proper action according to the data sensed by the sensors, there is a need to preserve the order of occurrence of the events until the data is processed at the sink/actor.

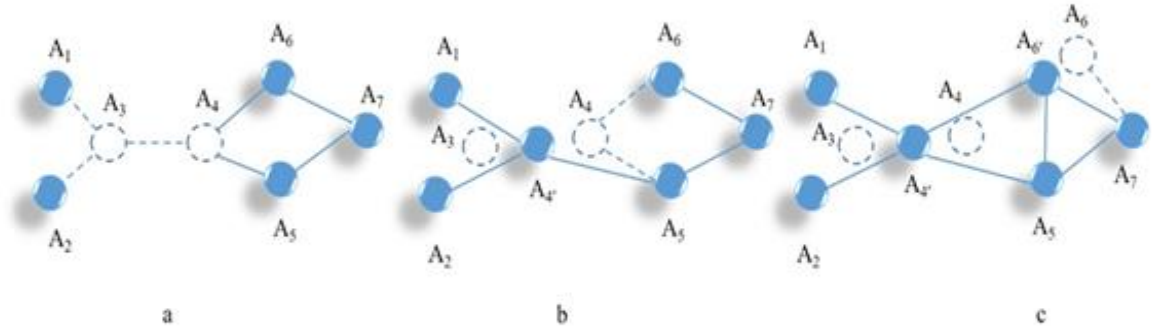


Fig.5. Cascading node motion for restoring connectivity

VI. PRESERVING TEMPORAL RELATIONSHIPS OF THE EVENTS

Temporal relationship of the events is determined with respect to the time of the event occurrences and events processing. If the events are processed in the same order as the order of their occurrences then the temporal relationship of the events is preserved. All the nodes must be synchronized to order all the events temporally i.e., timestamping method can be used and this particular timestamps should be correct all through that network. Nevertheless, to make sure the exact ordering of all the received events at the sink/actor, it is essential to ensure that there is no data in transit during the data ordering at sink/actor. In WSANs, observing physical environment characteristics which are liable to critical conditions is a smart activity [20] [21] [22]. But, many researches emphasis on minimizing the hop count in routing mechanism and rate of energy consumption without bearing in mind for ordering the messages according to their occurrence, such as in case of fire accident. Consider the example, from the fig. 6, It is clear that the correct ordering of messages is 1-2-3 as shown in fig. 6 (a), but not 1-3-2 as in fig. 6(b).

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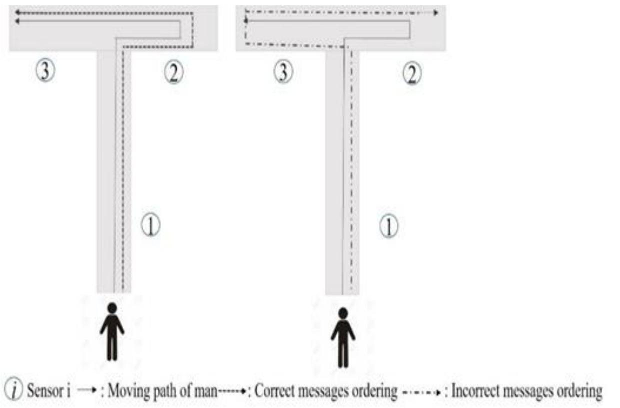
In [21] they proposed Ordering by confirmation protocol (OBC) for event ordering which can save much energy and can achieve lower latencies even in dense network and the rate of events and network dimension are increased. The OBC method cannot assure the rate at which the correct messages are ordered up to the maximum. To address that issue, an Ordering By Double Confirmation (OBDC) technique was developed to assure the rate of ordering of the right messages up to the maximum [23].



(a) (b)

Fig. 6. Valid and invalid ordering of messages
(a) Valid ordering (b) Invalid ordering

Conversely, the OBDC needs more time than the OBC method. In [24] they presented evaluating the performance of an algorithm to preserve temporal relationships of events which contains two modules that handle the issues of ordering the temporal events and also the synchronization of time. They also suggest an algorithm for tunable time synchronization that employs a synchronization scheme that suits for clustered topology. There are very few recent advancements in WSANs in terms of preserving the temporal relationship of the events. Good scope for exploration in research of this specific area is there, as there are lot of challenges to address. If the temporal relationships of the order of events is preserved and the data is processed at the sink/actor, then the accurate and suitable action can be taken and the purpose of the network will be fulfilled. The action should be taken by the actor with low latency and it should strive to meet the QoS parameters throughout the life time of the network.

VII. QUALITY OF SERVICE (QoS) IN WSANs

The cumulative demand for the usage of WSN applications in diverse areas makes the quality-of-service (QoS) as one of the principal concerns in WSN applications. Though no identical definition for QoS is found, multiple definitions are there that project technical characteristics to transfer information with respect to the types of application and the network infrastructure. QoS should guarantee the transfer of highest priority data to destination from a source while the delay and packet loss ratio will remain within tolerable limits [25]. Generally there exists two kinds of QoS in both wireless and wired networks, one is a hard QoS support and another is a soft QoS support. The applications which request the soft QoS are capable to receive a deprivation of QoS up to a certain degree on which that application is working still, as estimated [26]. On the other hand, applications which request for hard QoS support expect the assurance of identified parameters which signify hard constraints over throughput, latency etc. According to [27] [28] main factors that affect the QoS in sensor networks are throughput, latency, and packet delivery rate. There are three prominent models for providing QoS in communication networks, viz., Best effort, Integrated Services, and Differentiated Services. The Best Effort (BE) QoS model is the simplest of the above three models. It is the default QoS model used for Internet and it doesn't device any QoS mechanism at all. Integrated Services QoS model is known as Hard QoS model, and the Differentiated QoS model is known as the Soft QoS model. Fig. 7 shows the architecture and the prominent parameters that should be considered during service level agreements with respect to QoS.

A. Throughput

It is the amount of total bits of all the multi-hop flows within the network, received per second by the destination (network traffic at the sink).

B. Latency

The Mean of all the latencies from the received packets near sink, as defined in [29]:

$$t = \frac{\sum_{i=1}^{N}\sum_{j=1}^{k} t_{ij}}{N.K} \tag{5}$$

Where

t_{ij} = latency of j packet that is sent from i node
K = data packet number sent from each of the node
N = total count of nodes of the network

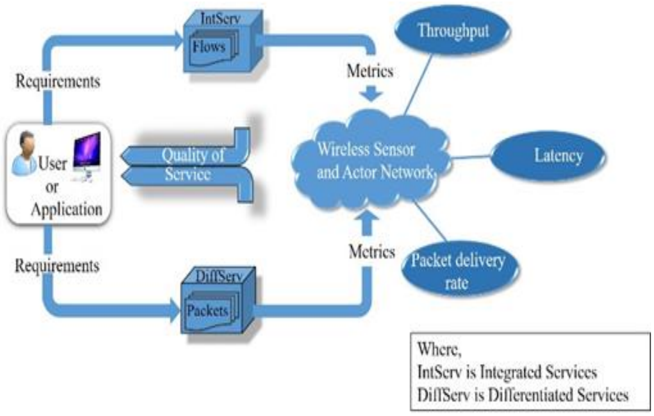


Fig.7. QoS architecture and parameters

C. Packet delivery rate

The ratio of the total number of packets that are generated to the total number of the packets that are received [30] near the sink (it is the reciprocal of the packet loss value) given as:

$$p = \frac{K_{sink}}{N.K} \tag{6}$$

Where K_{sink} = data packet number which is received at particular sink

K = number of data packet that is sent from each node

N = total count of nodes of the network

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Different aspects including clustering of the nodes, routing protocol, communication among the nodes etc., are meeting different QoS parameters individually in WSANs, but there need to be a possibly single policy that balances all the QoS metrics. Hence there is good scope for research in this aspect to propose a single method that addresses the possible proportion of the main QoS metrics of WSAN.

These above mentioned aspects play a major role in the operation of WSANs. Therefore the enhancements in these areas will lead to the effective utilization of the network resources. As the WSANs are being deployed in critical environments, there is a need to make it fully potential to meet the requirements of the aforementioned applications. Although there are active researches going on in this area currently, still there is a huge gap in making the WSANs more suitable for the time critical applications. As part of this work we have come up with identifying the major areas where the possible developments can be done with respect to the need for preserving temporal relationship of the events, restoring connectivity in case of node failures, and proposing the feasible proportion of different parameters of QoS.

VIII. Conclusion

Wireless Sensor and Actuator Networks are the collection of sensor nodes for sensing some physical phenomena and also few actor nodes to act in that field if a notable change in the environment is detected. Due to the alarming rate of growth of WSANs despite the advancements occurred recently, still there is a need for enhancements in order to meet the QoS metrics which are critical in deploying WSANs in industrial applications, battlefield surveillance, home automation, IoT etc. In this paper we presented different aspects of WSANs such as structure of a sensor node and actor node, cluster head election methods, communication and routing in along with different algorithms, connectivity restoration in case of failures of nodes, and we also gave a description of QoS, and identified some of the gaps in different areas of WSANs viz. coordination among the nodes, preserving the temporal relationship of the events, requirement of effective connectivity restoration algorithms, and QoS parameters.

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