Extensive Study on Coverage and Network Lifetime Issues in Wireless Sensor Networks

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ABSTRACT
Wireless sensor networks have a broad variation of applications within the surveillance, military, atmosphere monitoring and medical fields. Coverage and connectivity of sensor networks demonstrates how well a region is monitored. The coverage issues have been studied extensively. Particularly the coverage with respect to connectivity and network lifetime effectiveness is emphasized. Constructing a connected, absolutely encapsulated and energy efficient sensor network is efficacious for real time applications attributable to the restricted resources of sensor nodes. This extensive study highlights the recent research analysis and their respective approaches on coverage of wireless sensor networks. A comprehensive comparison among these approaches are given from the perspective of style objectives, assumptions, algorithm attributes and connected results.

Keywords
Wireless Sensor Network, Coverage, Connectivity, Lifetime, energy efficient.

1. INTRODUCTION
A characteristic wireless sensor network consists of an oversized variety of distributed sensor nodes cooperatively monitoring the physical world. Wireless sensor networks presents a brand new category of computing systems consisting of small and low-cost devices that are scattered within the setup so as to observe the spatial temporal phenomena around a person. Applications of wireless sensor networks embody environmental and habitat monitoring, precision agriculture, surveillance, asset tracking, and healthcare [1] [5]. Every node in an exceedingly wireless sensor network is often equipped with sensors, wireless communication devices, a microprocessor, and an influence supply. Sensor nodes are often placed on predetermined positions or randomly deployed. Nodes in an exceedingly sensor network communicate with one another by self organizing into ad-hoc wireless network. Compared to wireless ad-hoc networks, wireless sensor networks have restricted resources (such as energy, bandwidth, and computation) and huge dense deployments. A good deal of analysis has been conducted irrespective of the availability of restricted resources in the deployed area. Coverage downside is a crucial issue in wireless unintentional sensor network. Network coverage measures how well a parameter is monitored by a sensor network. If every position within the deployed area is monitored by a minimum of K ($K \geq 1$) sensors, the sensor network is claimed to be a K-coverage sensor network where K is the coverage degree. The coverage downside is actually a high quality of Service (QoS) that guarantees the monitored region is sensed by one or a lot of sensor nodes. In this paper, the present research developments on the coverage issues are described and presented. Energy conservation is an important issue in sensor networks because of replacement of battery is dear and even infeasible in some applications: like battle field surveillance. A frequently used methodology to conserve energy is scheduling, where a minimum variety of sensor nodes are activated to satisfy the K-coverage demand and also the remaining nodes are set to sleep for conserving the energy. Such scheduling schemes are used to prolong the lifetime of the sensor network. A further advantage of this approach is that it saves energy by avoiding frequent communication collisions and redundant messages in an exceedingly sensor network with dense activated nodes.

Much research has been done in recent years, investigating different aspects like, low power protocols, network establishments, routing protocol, coverage problems and the establishment of secure wireless sensor networks. A variety of protocols were proposed for prolonging the life of WSN and for routing the correct data to the base station [6], [7], [8]. These protocols cannot be used directly due to resource constraints of sensor nodes for resources like limited battery power, communication capability and computational speed. Even after many efforts, there are still many design options open for improvement and further research can be targeted to the specific applications. Therefore, there is a need to study alternate and/or new protocol which enables more efficient use of scarce resources at individual sensor nodes for an application. Section-2 discusses the prominent researches done towards network coverage issues in WSN. In Section-3 WSN coverage is dealt with. Section-4 highlights the lifetime efficient approaches. Section-5 highlights existing connectivity approaches used in WSN. Section-6 discusses the research gap through extensive study and it is followed by concluding remarks in Section 7. The recent survey of the existing research work based on coverage and lifetime optimization issues in peer-to-peer network is shown in Table 1.

2. NETWORK COVERAGE ISSUES IN WSN
Sensor nodes will transmit solely at short distances; long range communication is barely potential through hop-by-hop information forwarding. Wireless Sensor Nodes generates links with neighboring nodes in order that they'll communicate with one another. If a link between a ny nodes is broken they can't communicate with one another and therefore WSNs are highly obsessed on network connectivity. There are several reasons for a link failure between nodes, this paper attempts to categorize the link failure situations as sparse quantity of nodes, hostile attacks on nodes, security breach

Year	Author	Issue Focused	Approach used
2005	Frank Y. S. Lin P. L. Chiu [9]	Coverage and Discrimination Constraints	Lagrangean relaxation based heuristic technique
	Konstantinos e.t. al [10]	Energy Optimization	Genetic Algorithm
2006	Abhinay Venuturumilli [11]	Heterogeneous Connectivity	Self Organization of Transmission Ranges
	Mohamed K. Watfa [12]	Border Coverage Problem	Distributed Border Cover Selection Algorithm (2/3D)
2007	Jean-Marie Gorce e.t. al. [13]	Unreliable connectivity	Complete random graph
	Kevin Klues e.t. al [14]	Power Management	Unified Power Management Architecture
2008	Sergio Kostin e.t. al [15]	Connectivity issue k-neighbors problem	Site Specific Propagation Model
	Levendovszky e.t al. [16]	Balancing Energy	Combinatorial optimization
2009	Nor Azlina [17]	Coverage Issue	Strategical studies on Region of interest
	Wandeng e.t. al [18]	Balancing Network lifetime & Delay	Learning-based power efficient learning algorithm
2010	Flavio Fabbri and Chiara Buratti [19]	Connectivity and MAC performance	Multi-sink WSN
	George Zaki e.t. al [20]	Networks Lifetime Improvement	Enhanced LEACH
2011	Manh e.t. al [21]	Target Coverage Issue	-Minimal spanning tree -Triangle tile
	Sajjad e.t. al [22]	Network lifetime	Computational Intelligence
2012	Anand e.t. al[23]	Coverage and Connectivity	Distributed Coordinated Function
	Hailong e.t. al [24]	Limited battery life	-Integer programming -Packet Propagation Table Scheme

denial of service, energy depletion of nodes, environmental changes and mobility of nodes. A Wireless Sensor Network might consist of innumerous sensor nodes and the position of every node need not be essentially pre-engineered and placing the nodes in an orderly fashion is also impractical because they are deployed randomly through vehicle, helicopter or alternative means. The deployed nodes are also profusely scattered within the vast area and as a result, the nodes transmission is restricted resulting in network communication holes [25].

The second reason of nodes failure is that the nodes may get damaged due to physical reasons within the surroundings. Operating within the harsh environments may be a prime characteristic of WSNs, however these environments poses issue for network performance. Sensor nodes could also be crushed by the animals within the forest, by enemy troopers or tired within the battle field [26]. Network security breach can even be a reason for the nodes failure. A Wireless Sensor Network operating within the battle field is vulnerable than the networks operating in alternative surroundings. Nodes in this type of surroundings are more vulnerable to failure. Nodes could also be blocked, physically tampered through network security breach or captured by the enemy; these compromised nodes could minimize the network connectivity [27].

When WSNs operates for a limited time, its nodes starts to die due to restricted battery power and cannot be connected to the system which can disconnect some vital nodes from the access purpose. In such a scenario the chance of network partitioning or nodes separation is high. Radio transmission is additionally keen about the battery power and low battery power causes less transmission that ultimately causes dangerous connectivity [28]. The setting during which WSNs operate is also modified as a result of bound circumstances. As radio association is extremely sensitive to rain and growing plants that causes the network topology to vary. If a network is deployed in some cultivation fields or in forest the plants might have grown up when it slow the network has been deployed which can forestall the nodes to attach to every different resulting in an overall non-complete coverage [29].

Nodes in Wireless Sensor Network is also mobile where they'll move from one place to another as needed by the application or is also displaced by human and animals or might get carried by running water (if deployed within the sea). Mobility of nodes includes a huge impact on the network coverage. as an example, if information packet is long and also the node changes its current location throughout data packet forwarding, a part of the info is also lost at the receiving node or when a node selects a routing path however the nodes within the routing path might have modified their locations, it'll modify the coverage between supply and destination [30]. An answer to take care of or to re-establish network coverage is to get rid of the failed or compromised nodes that are making association issues and deploy a lot of nodes within the sensor field to eliminate the coverage drawback, however there are regions like battlefield, where nodes redeployment is not possible [26], thus WSNs' algorithmic schemes should be economical enough to beat coverage issues without human intervention.

3. WSN COVERAGE APPROACHES

Due to restricted resources of wireless sensor network coverage faces huge challenges. Totally different energy conservation or lifetime optimization strategies are presented to conserve network coverage for successful communication of the general network. There are 2 major network coverage approaches i.e. Clustering, and Virtual Backbone.

A. Clustering: Clustering is the method through which WSN is partitioned into multiple hierarchical parts (clusters) of sensors nodes. Every sensor is aware of its location with respect to the sensor field. All sensors nodes within the same cluster will communicate with one another directly (via one hop) and every sensor within the same cluster will communicate with all the nodes within the neighboring clusters directly. Within the same cluster only 1 node known as cluster head, needs to be active to keep up coverage. The active nodes take flip in spherical robin fashion [31] [32]. The duty cycle is inversely proportional to the amount of sensors within the same cluster. Examples of this coverage approach are discussed in GAF [33] [34] that partitions whole network into little squares through geographical grids and in every cell only 1 sensor node is kept active at any point of time that is accountable for coverage with different active nodes of the neighboring cells. Keeping only 1 node active in every cell conserves energy.

B. Virtual backbone: In this approach of coverage the network selects a subset of nodes that forms a connected backbone of bidirectional links towards the sink. So as to construct a completely connected backbone, every node should be related to a special backbone node such that it guarantees a bi-directional link towards the sink [35]. To construct the topology, SPAN in [36] has used virtual backbone technique for coverage. This technique of coverage selects a minimum range of nodes elected as backbone nodes, thereby increasing network lifetime and therefore the different nodes will visit sleep mode. Additionally, every sleeping node within the network ought to be connected with a minimum of one backbone node. This method additionally furnishes fault tolerance though scalability on the value of increased energy consumption because the energy consumption is inversely proportion to the backbone size.

Both clustering and virtual backbone approach of coverage have their own benefits and drawbacks, based on the necessities and also the setup where the sensor network are going to be deployed, this selection will decide whether clustering or virtual backbone methodology ought to be applied.

4. LIFETIME EFFICIENT APPROACHES

A capable WSN application is long-term supervision in hostile or distant environments. Using WSNs for military surveillance, as an example, involves deploying various sensors throughout the region of interest by aircraft to detect enemy activity or equipment. However, a key thought within the style of WSNs is that the power offer since replacing batteries in sensors is usually impractical. Though a substantial variety of studies have addressed energy potency problems in generic wireless adhoc networks, distributed sensing applications impose new constraints on sensor network coverage [2].

The issue of finding the most wide variety of covers to increase WSN lifetime has been modeled because the SET K-COVER problem [37]. Provided K covers, the lifetime of WSNs will ideally be extended by an element of K using the on top of approach beneath the coverage constraint. The SET K-COVER downside has been proven to be NP-complete. Beneath the belief $NP \neq P$, no precise algorithm will solve this downside in polynomial time. Some heuristic algorithms are presented, however they typically suffer from the trade-off between answer quality and running time. Recently proposed genetic algorithm (GA) can be used to cater out this trade-off [38]. The GA achieves near-optimal solutions in acceptable time however needs data on the worth of K or its higher certain, that is sometimes unobtainable. Additionally, such approaches rarely yield optimal solutions.

Soga [39] is employed for evaluating the effectiveness. The choice relies on elitism, where the N people with highest Coverage are passed on to the new generation. Its disadvantage is its tendency to supply a homogenized population early, with typically sub-optimal results. The disadvantage of SOGA is overcome in MOGA [39]. The GA itself is identical than the one utilized in the only objective case, with the exception of the choice, that should take in to consideration each objectives. Since the goal of the MOGA is to supply a uniformly populated PF, the weighted add approach was rejected since it assumes an a priori information of the user's preference of 1 objective over the opposite. Many schemes were devised to include each objective within the choice and as within the case for the SOGA the deterministic elitist choice outperformed Binary Tournament and Roulette Wheel choice.

The many aspects of the WSN lifetime drawback includes sensor activity scheduling [37] network structure [2], information aggregation [40-41], and routing protocol [42][43]. This study focuses on sensor activity scheduling. The drawback of extending WSN lifetime by sensor activity scheduling was initial modeled because the SET K-COVER problem by Slijep, cevic and Potkonjak [44]. They proved the NP-completeness of this drawback by reduction from the minimum cowl drawback [45]. To unravel this drawback, the authors proposed the foremost constrained minimally constraining covering heuristic (MCMCC). This approach runs in polynomial time however usually yields unsatisfactory results. Cardei and Du[2] formulated WSN lifetime extension because the disjoint set covers (DSC) drawback, that is equivalent to the SET K-COVER drawback.

Cardei and Du [2] introduced a heuristic algorithm, referred to as most covers using Mixed Integer Programming (MCMIP), to resolve the DSC drawback. Though the MCMIP methodology will realize the optimal resolution, its implicit exhaustive search needs exponential running time. The higher end approaches for extending WSN lifetime however suffer from the trade-off between resolution quality and running time. For the SET K-COVER drawback, the MCMCC takes solely polynomial time however typically yields unsatisfactory solutions. On the opposite side, the MCMIP ensures optimal solutions however at the value of exponential time complexity. To deal with this issue, Damin [39] designed an integer-coded GA which generates $C_i \in N$ indicates the cluster range assigned to sensor Si, and a chromosome represents the cluster arrangement of all sensors for covers. Within the course of evolution, the teams gradually type covers, i.e., they satisfy the constraint of full coverage. Studies have demonstrated that this algorithm outperforms MCMCC in terms of the quantity of covers and is far faster than MCMIP. Nevertheless, one defect is that, thanks to the integer illustration of chromosomes, this GA needs an higher certain on the quantity of covers, that is typically unobtainable. Moreover, like most different GAs, the proposed GA rarely yields optimal solutions. Therefore, an algorithm is required to consistently deliver, among an appropriate running time, sensible activity schedules for extending WSN lifetime. The several methods used for increasing the coverage and connectivity of wireless sensor networks and these methods are re-discussed below:

- SET K-COVER Problem: [37] the issue is to arrange mutually exclusive sensor nodes into variety of covers or sets each of which might absolutely cover the monitoring space A. The activity length for every cowl is same and the energy consumption is uniform among nodes. Because the lifetime of the network is directly proportional with the quantity of allotted covers, the goal is to maximize the quantity of covers.
- Low Power Coverage: [46] ILP1 formulations for the Minimum0-1 coverage, Minimal coverage with Sensor Field Intensity and Balanced Operation Scheduling issues. The Minimum 0-1 coverage tries to seek out the

minimum variety of sensors which will cowl the whole monitoring space a minute the Minimal coverage with Sensor Field Intensity tries to attain constant goal with the guarantee that the sensor field intensity for every region of A is on top of a user specified threshold price

- Target Coverage: [2] It is an economical target coverage mechanism for sensor networks. The strategy is to maximize the network lifetime by organizing sensors into the maximal variety of set covers. These set covers are activated successively such that at any given time solely a collection is active. The nodes from the active set are within the active state whereas all the others are within the sleep state. A key distinction between this approach and [1] is that the sensor nodes will participate in multiple sets (the covers don't contain mutually exclusive nodes). The only restriction is that the total of all time weights related to the sets a node belongs to must be one. Another distinction is that this approach covers a collection of targets, not a region as we've seen in previous works. They formalize the most Set Covers (MSC) downside and that they prove that's NP-complete.
- Preserving Coverage: [47] A distributed and localized node scheduling algorithm competent to attenuate the quantity of active nodes whereas preserving space coverage. The scheduling runs in rounds. Every iteration starts with a self-scheduling part during which every node investigate its off-duty eligibility. Specifically, if a node's sensing vary is sufficiently coated by its neighbors is eligible to show off and save energy
- CCP: CCP or Coverage Configuration Protocol [48] is in initial primary solutions that attempt to attain each coverage and connectivity in a single protocol. CCP decides if a sensor node should be active or not according with the particular coverage of its sensing space. If its sensing space is already sufficiently lined by the neighboring nodes, the node is often Inactive and enters within the SLEEP mode. A node is often in three states: SLEEP, LISTEN and ACTIVE. Within the SLEEP mode a node sleeps to conserve energy. In ACTIVE state the node actively senses the surroundings and communicates with different sensors. CCP ensures connectivity for this explicit case, but sparse connectivity is ensured within the middle of the network.
- PEAS: PEAS [49] uses an equivalent technique for turning off nodes. However, PEAS style targets majority of hostile surroundings where: i) node failures are high, ii) the node deployment density is high and iii) attributable to hardware limitations, and sensor nodes cannot run complicated protocols. PEAS protocol is easy and consists of 2 algorithms: Probing surroundings that determines that nodes ought to work and Adaptive Sleeping, that determines the way to dynamically change the sensors' sleep times so as to stay in a relentless wake-up state. At the start all the nodes are sleeping for exponentially distributed random time. When nodes wakes-up, it broadcasts a search message at intervals an explicit vary R_p. Any operating node that receives the message responds with a REPLY. There will be no relationships between sensing and communication ranges neither specified nor sturdy coverage or connectivity guarantees.

OGDC: The Optimal Geographical Density management algorithm is another answer that minimize the quantity of active sensors used to conserve energy whereas making certain coverage and connectivity preservation in high density sensor networks. The same theorem [40] simplifies the integrated connected coverage drawback. Additionally, they conjointly devise many optimality conditions for covering a locality A with the minimum overlap of the lined neighbor areas. OGDC that a reduce range of deployed nodes are needed to attain coverage. OGDC uses rounds and so need time synchronization among nodes. OGDC tries to optimize the set of active nodes primarily based on their relative location (optimality conditions) whenever doable.

5. CONNECTIVITY RECOVERY TECHNIQUES FOR WSNs

WSNs are event based mostly and operate completely in several environments having different applications than conventional wired networks and possess different environmental and application needs. Developing and maintaining network connectivity is crucial for the successful operation of WSNs. the matter of network connectivity has been addressed through totally different strategies. Various network connectivity schemes are proposed that have proven to be economical and effective for the network connectivity. This section attempts to classify these strategies.

1) Nodes planned placement: The position of node is the most significant issue for communication in WSNs. Deploying nodes randomly will increase the chance of communication gaps and network connectivity downside. If nodes deployment is finished during a purposeful manner, it will scale back the connectivity downside by reducing the probabilities of network communication and coverage gaps [50].
2) Mobile agent nodes: Srinidhi et al [51] have discussed about topology management with respect to network connectivity and propose a network connectivity theme that describes an approach of PILOT (Pre-defined, Intelligent, light-weight topology management) nodes that are light-weight mobile nodes. Whenever a link between traditional nodes is anticipated to be failed a pilot node will be positioned and takes place of the failing node to avert the link failure. This theme works well and provides sufficient network connectivity, however might not be appropriate in eventualities where the sphere is uneven and mobility of the nodes isn't simple. Mobility conjointly involves mechanical work that consumes a lot of power that ultimately decreases the lifetime of pilot nodes. Speed and on time availability of pilot nodes ought to even be thought of. In [52] an analogous plan of mobile nodes is mentioned, however the mobile nodes are literally robotics that deploys routing nodes on predetermined locations for higher routing and connectivity.
3) Nodes planned Redistribution: Redistribution of nodes is the easiest method to tackle the matter of network connectivity. If this redeployment is well planed and also the location where the nodes are redeployed is predetermined the probabilities of communication gap are less. W.K.G. Seah, et al [53] provides a network connectivity technique within which mobiles robots and static nodes mutually support one another. Static nodes function landmarks and facilitate robots explore for targets whereas. Mobile robots determine the crucial sensor space where the network communication and coverage is poor owing to low density or some network

interference and move to fill the gap by deploying sensor nodes to reinforce the sensing coverage and connectivity.

4) Best neighbour selection: Navid et al [31] have introduced a technique that describes the standard of connectivity (QOC) that identifies and extracts the attempt of best nodes that are linked to various nodes over a time, and use this quality because the criteria for most well-liked neighbour election thus on cut back the likelihood of link failure. An identical approach in [28], the connectivity between failing nodes is maintained by developing a Power-CDS (Connected Dominating Set) protocol for constructing a virtual backbone that may tolerate consecutive failures. In keeping with this strategy, the sink node selects some nodes with a high energy as backup coordinators and places them to sleep, whereas different nodes are normally operating as knowledge sending and receiving. The backup coordinators are invoked when a link failure between its neighbour nodes is detected. This theme saves energy by connecting minimum connected dominating sets and also the topology may be recovered by adjusting the transmission ranges of the coordinators and backup coordinators.

5) Smart antennas: A research work by Sonu Shankar et al [54] has presented enhanced connectivity results employing a hybrid approach towards sensible antennas that uses a beam formation technique that utilizes signal processing techniques to manage the sensitivity and direction of antenna radiation patterns in sensor networks.

6) Cooperative sensing: A solution for better connectivity and communication coverage is proposed in [25] is right hybrid Multi-Hop cooperation Transmission using cooperative transmission to heal the link failure occurred because of nodes short communication as described earlier provides maximum connectivity, by increasing the communication variations in the nodes collectively leads to reestablishment of connectivity among disconnected nodes within the network. Density includes a positive impact on this theme as a lot of nodes begin transmission collectively produces high power signals, however there's still a general trade-off between connectivity and energy utilization.

6. IDENTIFYING RESEARCH GAP

Connectivity failure throughout the network operation may be a biggest issue as WSNs are knowledge centric and connectivity failure leads to knowledge loss and network partitioning. In this survey, the WSNs' connectivity failure problems and currently developed connectivity schemes are also discussed in previous sections. It can be said concluded that WSNs are application specific and it's not possible for the present network connectivity themes that one network connectivity scheme can outperform in all situations. Currently developed network connectivity schemes might perform well for a few specific applications in exceedingly specific surroundings; however it might not perform well if applied to a unique application, operating in exceedingly totally different surroundings. The variations in the assigned radio signal affects connectivity. Density of the connected common nodes in an exceedingly cluster contains a huge impact on the performance of cluster leader, because it can stay busy all the time. As a pacesetter of an enormous cluster the chance of the cluster leader failure is high, thus an energetic node should have an optimum variety of sleeping nodes connected with it, and a controlled assigned vary is important for the sensor nodes to stay connected with potential minimum energy consumption and forestall the network partitioning.

Most recent research works on the wireless sensor network coverage issues are still restricted to theoretical studies [2]. Future analysis specializing in solutions that catalyzed sensible deployment may be conducted. The factors of research gaps identified are:

A. Coverage solutions for sensors with irregular sensing/communication range: In real-time sensor networks, the sensing and communication vary are irregular. For instance, the directional antenna, that is employed broadly in surveillance, contains a sector sensing vary. The communication vary of the sensor isn't a perfect circle. The solution for the coverage of a sensor network whose sensor node has an irregular sensing or communication vary is important in globe applications.

B. Coverage solutions for mobile sensor networks: In a mobile sensor network, the sensor nodes are mobile and that they move during deployment. The movement of sensors may well be caused by the setup they're in or by the actuator they need. The coverage answer during this sort of sensor network can be studied.

C. Coverage solutions with fault tolerance: Fault tolerance is the ability to maintain sensor network functionalities with none interruption thanks to sensor node failures [1]. Fault tolerance ought to be thought of whereas configuring a connected and totally lined sensor network. The failure of sensor nodes shouldn't have an effect on the coverage and connectivity of a wireless sensor network.

D. Other energy conservation methods besides scheduling: In order to preserve energy in a frequently used sensor network, scheduling could be a frequently used methodology. Besides scheduling, reducing communication vary additionally conserves energy. The paper has reviewed the way to maintain the connectivity and coverage when communication range is reduced and the way abundant ought to be reduced, but optimal solution is not yet found for benchmarking.

E. Coverage solutions for specific applications: Certain applications, like tracking and detection, might use specific coverage solutions. The solutions ought to dynamically confirm that sensor ought to sense and what has to be sensed whereas considering the energy conservation.

7. CONCLUSION

As a vital analysis issue, the coverage problem has been studied extensively, and plenty of solutions are proposed. Some solutions specialize in pure coverage issues to characterize the coverage of wireless circumstantial sensor networks. Alternative solutions integrate network connectivity into coverage issues. Network connectivity, that indicates whether or not any 2 nodes in an exceedingly sensor network will communicate with one another, is critical for successful information transmission. Algorithms to construct a sensor network with connected coverage are efficacious to universal applications. Furthermore, minimizing the energy consumption to prolong the lifetime of a sensor network is taken into account. Some algorithms and protocols are designed to realize energy potency whereas maintaining a completely coated connected wireless circumstantial sensor network. Wireless sensor nodes are resource constrained and largely operate in unsafe environments. Displacement, communication blockage and frequent failure of wireless sensor nodes cause network topology to become intolerably dynamic that affects network connectivity. Lack of topological connectivity between nodes might lead the complete network to interrupt apart into disconnected items. The disconnected sub-networks could also be unable to speak with the sink, hence cannot send its information to base station. Several researchers have devoted their efforts to develop network communication schemes that have proven higher network connectivity, communication performance and prolonged network lifetime. In this paper a summary of the present network connectivity schemes and analysis of existing connectivity issues are presented.

8. REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci. Wireless sensor networks: A survey. Computer Networks, 38(4):393-422, March 2002.

[2] M. Cardei and J. Wu. Energy-efficient coverage problems in wireless ad hoc sensor networks. Computer Communications, 29(4):413-420, 2005.

[3] J. Carle and D. Simplot-Ryl. Energy efficient area monitoring for sensor networks. Computer, 37(2):40-46, IEEE Computer Society, February 2004.

[4] B. Chen, K. Jamieson, H. Balakrishnan, and R. Morris. Span: An energy-efficient coordination algorithm for topology maintenance in ad hoc wireless networks. ACM/IEEE MobiCom, 2001.

[5] D. Culler, D. Estrin, and M. Srivastava. Overview of sensor networks. Computer (Long Beach, CA), 37:88, 41-49, IEEE Computer Society, 2004.

[6] G. Martin, .An Evaluation of Ad-hoc Routing Protocols for Wireless Sensor Networks., Master’s thesis, School of Computing Science, Newcastle University upon Tyne, U.K., May 2004.

[7] W.R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, .Energy-efficient Communication Protocol for Wireless Microsensor Networks., in IEEE Computer Society Proceedings of the Thirty Third Hawaii International Conference on System Sciences (HICSS '00), Washington, DC, USA, Jan. 2000, vol. 8, pp. 8020.

[8] W.R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, .An Application-Specific Protocol Architecture for Wireless Microsensor Networks. In IEEE Tmnsactions on Wireless Communications (October 2002), vol. 1(4), pp. 660-670.

[9] Frank Y. S. Lin, P. L. Chiu, Energy-Efficient Sensor Network Design Subject to Complete Coverage and Discrimination Constraints, IEEE SECON 2005

[10] Konstantinos P. Ferentinos, Theodore A. Tsiligiridis, Konstantinos G. Arvanitis, Energy Optimization of Wireless Sensor Networks for Environmental Measurements, Computational Intelligence for Measurement Systems and Applications Giardini Naxos, Italy, 20-22 July 2005

[11] Abhinay Venuturumilli, Achieving Robust Wireless Sensor Networks through Self Organization of Heterogeneous Connectivity, Master’s Thesis, 2006

[12] Mohamed K. Watfa, Sesh Commuri, Power Conservation Approaches to the Border Coverage Problem in Wireless Sensor Networks, ICWN 06

[13] Jean-Marie Gorce, Ruifeng Zhang, and Herv´e Parvery, Impact of Radio Link Unreliability on the Connectivity of Wireless Sensor Networks, EURASIP Journal onWireless Communications and Networking Volume 2007, Article ID 19196, 16 pages

[14] Kevin Klues, Guoliang Xing, Chenyang Lu, Towards a Unified Power Management Architecture for Wireless Sensor Network, 2006

[15] Sergio Kostin_, Leonardo Bidese de Pinho and Claudio Luis de Amorim, The Impact of Office Dimension, Layout, Path Loss Exponent, and Multipath Fading on the k-Neighbors Connectivity Problem,Retrieved from http://www.cos.ufrj.br/uploadfiles/1204741860.pdf

[16] J. Levendovszky, A. Bojárszky, B. Karlócai, A. Oláh, Energy balancing by combinatorial optimization for wireless sensor Networks, WSEAS transactions on communications, ISSN: 1109-2742, Issue 2, Volume 7, February 2008

[17] Nor Azlina Ab. Aziz, Kamarulzaman Ab. Aziz, and Wan Zakiah Wan Ismail, Coverage Strategies for Wireless Sensor Networks, World Academy of Science, Engineering and Technology 50 2009

[18] W.U Wandeng, Xu Deju, Zhu Yihua, Shen Zhenwei, Tang Yiping, Learning-based Power Efficient Routing Algorithms Balancing Network Lifetime and Packet Delay for Wireless Sensor Network, Chinese Journal of Electronics, Vol.18, No.4, oct 2009

[19] Flavio Fabbri and Chiara Buratti, Throughput Analysis of Wireless Sensor Networks via Evaluation of Connectivity and MAC performance, Emerging Communications for Wireless Sensor Networks, 2010

[20] George Zaki1, Nora Ali, Ramez Daoud, Hany ElSayed, Node Deployment and Mobile Sinks for Wireless Sensor Networks Lifetime Improvement, Sustainable Wireless Sensor Networks, 2010

[21] Manh Thuong Quan Dao1, Ngoc Duy Nguyen1, Vyacheslav Zalyubovskiy2, and Hyunseung Choo1, An Energy-efficient Coverage Pattern of WSNs for High Rate Data Transmissions, Retrieved from http://world-comp.org/p2011/ICW8239.pdf

[22] Sajjad Hussain Shah, Kashif Naseer, Wajid Ali, Sohail Jabbar, Abid Ali Minhas, Prolonging the Network Life Time in WSN through Computational Intelligence, Proceedings of the World Congress on Engineering and Computer Science 2011 Vol I, WCECS 2011, October 19-21, 2011, San Francisco, USA

[23] D.G. Anand, H.G. Chandrakanth, M.N. Giriprasad, An Efficient Energy, Coverage and Connectivity (EC2) Algorithm for Wireless Sensor Network, International Journal of Computer Applications (0975 – 8887) Volume 45– No.6, May 2012

[24] Hailong Li, Vaibhav Pandit, Yang Chi, and Dharma P. Agrawal, Lifetime Optimization of Wireless Sensor Networks with Packet Propagation Table, IEEE ICC 2012

[25] Albert Krohn, Michael Beigl, Christian Decker, Till Riedel, Tobias Zimmer, and David Garces (2006) "Increasing connectivity in wireless sensor network using cooperative transmission" 3rd International Conference on Networked Sensing Systems (INSS), Chicago, USA, May 31- June 2 2006.

[26] Akyildiz, Weilian Su, Yogesh Sankarasubramaniam and Erdal Cayirci (2002) "A survey on sensor networks" Communications Magazine, IEEE 40(8): 102-114.

[27] Adrian Perrig, John Stankovic, and David Wagner (2004) "Securtiy in Wireless Sensor Networks" COMMUNICATIONS OF THE ACM June 2004/Vol. 47, No. 6, pp. 53-57.

[28] ChiuWen, C. K. S. a. H. C. J. (2007) "Fault-Tolerant Topology Control with Adjustable Transmission Ranges in Wireless Sensor Networks" Proceedings of the 13th Pacific Rim International Symposium on Dependable Computing: 131-138.

[29] John Thelen, Dann Goense, and Koen Langendoen (2005) "Radio wave propagation in potato fields" 1st Workshop on Wireless Network Measurements, Trentino, Italy, April 2005.

[30] Sungsoon Cho and John P. Hayes (2005) "Impact of Mobility on Connection Stability in ad hoc networks" Wireless Communications and Networking Conference, 2005 IEEE.

[31] Navid Nikaein and Christian Bonnet (2004) "Topology Management for Improving Routing and Network Performances in Mobile Ad Hoc Networks" Mobile Networks and Applications (Kluwer Academic Publishers) Volume 9(6): 583 – 594.

[32] Chih-fan Hsin and Mingyan Liu "Partial Clustering: Maintaining Connectivity in a Low Duty-Cycled Dense Wireless Sensor Network" 19th IEEE International Conference on Parallel and Distributed Processing Symposium, 2005. Proceedings: 8.

[33] Ya Xu, John Heidemann and D. Estrin (2001) "GeographyInformed energy conservation for ad hoc routing" ACM/IEEE International Conference on Mobile Computing and Networking (MOBICOM), 2001.

[34] Stefano Basagni, Alessio Carosi and Chiara Petrioli (2008) "Reliable Grouping GAF Algorithm using Hexagonal Virtual Cell Structure" 3rd International Conference on Sensing Technology, 2008. ICST 2008: 600 – 603.

[35] Rong Yu, Zhi Sun, and Shunliang Mei (2007) "Scalable Topology and Energy Management in Wireless Sensor Networks" Wireless Communications and Networking Conference, 2007.WCNC 2007 IEEE: 3448 – 3453.

[36] B. Chen, K. J., H. Balakrishnan, and R. Morris (2001) "Span: An energy-efficient coordination algorithm for topology maintenance in ad hoc wireless networks" ACM/IEEE International Conference on Mobile Computing and Networking (MOBICOM) 2001.

[37] S. Slijepcevic, M. Potkonjak, Power efficient organization of wireless sensor networks, in: Proceedings of the IEEE international conference on communications, vol. 2, 2001, pp. 472–476

[38] C.C. Lai, C.K. Ting, R.S. Ko, An effective genetic algorithm to improve wireless sensor network lifetime for large-scale surveillance applications, in: Proceedings of the 2007 Congress on Evolutionary Computation, 2007, pp. 3531–3538

[39] Damien Jourdan ,"Node placement for a wireless sensor network using a multi objective genetic algorithm.

[40] Zhang. B.S. Lee, X.S. Wang, Aggregation in sensor networks with a user-provided quality of service goal, Information Sciences 178 (9) (2008) 2128–2149

[41] L. Krishnamachari, D. Estrin, S. Wicker, The impact of data aggregation in wireless sensor networks, in: Proceedings of the 22nd International Conference on Distributed Computing Systems Workshop, 2002, pp. 575–578, 2002

[42] W.R. Heinzelman, A. Chandrakasan, H. Balakrishnan, Energy-efficient communication protocol for wireless microsensor networks, in: Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, 2000, pp. 1–10.

[43] C. Ok, S. Lee, P. Mitra, S. Kumara, Distributed routing in wireless sensor networks using energy welfare metric, Information Sciences 180 (9) (2010) 1656–1670

[44] B. Badrinath, J. Scholtz, M. Srivastava, K. Mills, V. Stanford, IEEE, IEEE Personal Communication, 2000 (Special issue on smart spaces and environments

[45] F. Marcelloni, M. Vecchio, Enabling energy-efficient and lossy-aware data compression in wireless sensor networks by multi-objective evolutionary optimization, Information Sciences 180 (10) (2010) 1924–1941.

[46] S. Meguerdichian and M. Potkonjak, "Low power 0/1 coverage and scheduling techniques in sensor networks," Tech. Rep. 030001, University of California at Los Angles, January 2003.

[47] D. Tian and N. D. Georganas, "A coverage-preserving node scheduling scheme for large wireless sensor networks," in WSNA '02: Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications. New York, NY,USA: ACM, 2002, pp. 32–41.

[48] G. Xing, X. Wang, Y. Zhang, C. Lu, R. Pless , and C. Gill, "Integrated coverage and connectivity configuration for energy conservation in sensor networks," ACM Trans. Sen. Netw., vol. 1, no. 1, pp. 36–72, 2000

[49] F. Ye, G. Zhong, J. Cheng, S. Lu, and L. Zhang, "Peas: A robust energy conserving protocol for long-lived sensor networks," in ICDCS '03: Proceedings of the 23rd International Conference on Distributed Computing Systems. Washington, DC, USA: IEEE Computer Society, 2003, p. 28

[50] You-Chiun Wang, Chun-Chi Hu, and Yu-Chee Tseng "Efficient Placement and Dispatch of Sensors in a Wireless Sensor Network" IEEE transactions on mobile computing, Vol. 7, No. 2, February 2008, pp. 262-274.

[51] Srinidhi T, Sridhar G. and Sridhar V (2003) "Topology Management in Ad Hoc Mobile Wireless Networks" Real-Time Systems Symposium, Work-in-Progress Session.

[52] Bogdan Ciubotaru, Razvan Cioarga, Dan Chiciudean, Mihai V. Micea and Mircea Stratulat (2007) "Connectivity Improvement in Wireless Sensor Networks Based on Mobile Nodes" Instrumentation and Measurement Technology Conference -IMTC 2007 Warsaw, Poland, May 1-3, 2007.

[53] Winston K.G. Seah, Kevin Z. Liu, J. G. Lim, S.V. Rao and Marcelo H. Ang, Jr "TARANTULAS: Mobility-enhanced wireless sensor-actuator networks" in: International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing, vol. 1, June 2006, pp. 548_551.

[54] Sonu Shankar and Deepa Kundur (2008) "Towards improved connectivity with hybrid uni/omni-directional antennas in wireless sensor networks" IEEE Conference on Computer Communications Workshops, 2008. INFOCOM, pp. 1 – 4.

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