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To Develop Reliable Transmission in Wireless Sensor Networks: A Survey

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***Abstract* -- A Wireless Sensor Network (WSN) is a wireless network consisting of relatively large number of sensor nodes to monitor physical or environmental conditions. WSN are currently receiving significant attention due to their wide range of applications such as environment monitoring, traffic surveillance, building structures monitoring, military sensing and information gathering, habitat monitoring, wildfire detection, pollution monitoring, etc. The issues and requirements of reliability development mechanism depend on the available resources and application for which the WSN is deployed. This paper deals with the various documents that have been reviewed to develop reliable transmission in wireless sensor networks. This paper is divided in to six sections. It begins with a brief overview of WSN. In section two, related to multicast routing protocol is reviewed and explored technical challenges and issues associated with this. In section three, related to Connected Dominating Set (CDS) in multicast routing protocol is reviewed. In section four, related to Random Linear Network Coding (RLNC) in multicast routing protocol is reviewed. In section five, related to Minimum Connected Dominating Set (MCDS) in multicast routing protocol is reviewed. In section six, related to Identity-Based Cryptography (IBC) in multicast routing protocol is reviewed.**

Keywords: Multicast routing protocol, connected dominating set, random linear network coding, minimum connected dominating set, identity-based cryptography.

I. SURVEY ON WIRELESS SENSOR NETWORK

Recently, WSN is one of the emerging dominant technology trends in wireless networks. WSN are likely to be composed of hundreds, and potentially thousands of tiny sensor nodes and functioning autonomously in wireless environment. Since sensor nodes have limited battery life, limited processing capability, limited memory and the need for ubiquitous, invisible deployments will result in small sized, resource-constrained sensor nodes are paramount importance in the design of sensor network protocols. WSN are currently receiving significant attention due to their wide range of applications such as environment monitoring, traffic surveillance, building structures monitoring, military sensing and information gathering, habitat monitoring, wildfire detection, pollution monitoring, etc (I.F. Akyildiz et al, 2002).

Akyildiz et al (2002) explored sensor network applications and sensing tasks, provided a review of factors influencing the design of sensor networks and outlined the communication architecture for sensor network, also discussed that open research issues for the realization of sensor networks, explored the algorithms and protocols developed for each layer in the literature. Deepak Ganesan et al (2003) discussed about the key networking challenges in sensor networks including more recent techniques. (i.e) power, data management, routing, geographic routing challenges, monitoring and maintenance of such dynamic, resource-limited systems. Ittipong Khemapech et al (2005) examined on sensor network simulators for development and simulating WSN and compared them.

Routing in WSN has been very complex and challenging due to their intrinsic characteristics that differentiate them from other legacy wireless networks. Routing protocol should aim to reduce the energy consumed per packet. However, one of the major challenges is the uneven distribution of sensor nodes. Due to the uneven topology, some intermediate nodes may expend more energy when transmitting packets. Proposing a global addressing scheme in WSN is very challenging, due to relatively large number of sensor nodes. Designing position-aware sensor networks is another challenge. One of the fundamental operations in WSN is data dissemination from sensor nodes to their sink nodes and vice-versa. This is usually achieved by performing a unicast, multicast, broadcast and geocast. Unicast operation is a one-to-one operation. Jamal N. A et al (2006) presented a survey of the state-of-the-art unicast routing techniques in WSN and provided design challenges and advantages of unicast routing protocols, also classified the routing techniques into three categories based on the underlying network structure: flat, hierarchical, and location-based routing also depending on the protocol operation classified into multipath-based, query-based, negotiation-based, QoS-based, and coherent-based protocols. The multicasting mechanism is one-to-many. In this operation, packets are disseminated from one source to multiple destinations. Broadcast operation is a one-to-all operation, in which packets are disseminated from a source to all the nodes in the network. Broadcasting can be broadly classified into simple broadcast schemes, probability-based broadcasting, neighborhood-aware broadcast mechanism, location-aided broadcasting, energy-efficient broadcasting and reliable broadcasting. In geocasting, dissemination of packets is done in a set of nodes belonging to a specified area.

II. SURVEY ON MULTICAST ROUTING PROTOCOL

In Multicast routing, a sink node can send multicast messages to a selected set of sensor nodes. One of the main objectives of this multicasting is to improve the overall efficiency of the network by decreasing the number of forwarding nodes. Xin Li and ShuBo Qiu (2011) analyzed variety of multicast routing protocols in WSN and according to the principle, it is classified into four categories: a) Tree-based multicast routing protocols, b) Energy-based multicast routing protocols, c)Group location-based multicast and d) IP based multicast routing protocols.

M.Simek et al (2008) described main principles, advantages and shortcomings of the multicast routing protocols for wireless sensor networks. The multicast routing protocol is mainly classified into three categories reactive, proactive and hybrid. The reactive routing protocol called as on-demand routing protocol (Md.Arafatur Rahman and Farhat Anwar, 2010), the proactive routing protocol called as table-driven routing protocol. The hybrid routing protocol is combination of both reactive and proactive (Luo Junhai et al, 2008).

Example for reactive multicast routing protocol is: ODMRP (S.J. Lee, 2002), MAODV (E.M. Royer and C.E. Perkins, 2000) and PUMA (R. Vaishampayan and J. J. Garcia, 2004). Sung-Ju Lee et al (2002) evaluated the scalability and performance of ODMRP for adhoc wireless networks. In 2004, R.Vaishampayan et al (2004) compared the mesh based and tree based multicast routing in MANET with varying the parameters of mobility, group members, number of senders, traffic nodes and the number of multicast groups and concluded that PUMA attains higher packet delivery ratios than ODMRP and MAODV. In 2007, Andrea Detti et al proved that OBAMP has a low-latency and a high delivery ratio, even when the group size increases by analyze the performance of OBAMP and compared it with two state-of-the-art protocols, namely ODMRP and ALMA. In 2011, Pandi Selvam et al compared the performance of two on-demand multicast routing protocols, namely MAODV and ODMRP in MANET. In 2012, Sejal Butani et al chosen PUMA for multicast ad hoc network based on comparison of various multicasting protocol and concluded that PUMA provides less routing overhead, high throughput and better packet delivery ratio as compared to MAODV and ODMRP in MANET. Performance comparison among ODMRP, MAODV, PUMA, OBAMP, ALMA and ALMA-H of MANET and Wireless Mesh Network (WMN) multicast routing protocols (Reactive, Proactive and Hybrid) is already done by the researchers (S.J. Lee et al, 2002; R.Vaishampayan et al, 2004; Andrea Detti et al, 2007; J. J. Garcia, 2004) whereas Adamu, M.Z et al (2012) compared the different MANET routing protocols and presented a comprehensive survey in WSN, Abid ali minhas et al (2011) compared the MAODV, TEEN (Threshold-Sensitive Energy Efficient Sensor Network), SPEED (A Stateless Protocol for Real-Time Communication) T. He, et al (2003), MMSPEED (Multi-path and Multi-SPEED) for WSN and also some simulation results have been published before. Katia Obraczka et al (2002) discussed about variety of multicast routing issues in MANET.

Jing Dong et al (2011) demonstrated secure, high throughput multicast routing protocol in ODMRP for wireless mesh networks using well known routing metrics Success Probability Product (SPP) and Expected Transmission Count (ETX). In 2007, Sabyasachi Roy et al studied routing metrics for high-throughput tree or mesh construction in ODMRP and showed from their experiment that ODMRP achieves high throughput using SPP and PP. Xin Zhao et al (2011) proposed a routing metric namely, Expected Multicast Transmission Time (EMTT) for enabling high throughput reliable multicast in multi-rate Wireless Mesh Networks (WMN) and concluded that EMTT metric effectively reduces the overall multicast transmission time while yielding higher packet delivery ratio and lower end-to-end latency in WMN. Dalia Malki and Michael Reiter (1996) presented a high-throughput secure reliable multicast protocol that is suitable for use in asynchronous distributed systems and that can tolerate the malicious behavior of up to less than one-third of the destination group members. Dimitrios Koutsonikolas et al (2012) proposed a new high-throughput, reliable multicast protocol for WMNs named, pacifier and compared its performance against MORE (S. Chachulski et al, 2007).

III. SURVEY ON CONNECTED DOMINATING SET

Recently, Connected Dominating Set (CDS) is a promising approach to deliver a multicast data in high throughput for WSN (Najla A.N et al, 2012). Some researchers have proposed to construct a virtual backbone by nodes in a CDS to improve performances of multicast routing in wireless ad hoc networks. Since only nodes in a CDS multicast messages, it is desirable to find a CDS of small number of nodes for a given network (B. Das, 1997; J. Wu, 1999; K. Alzoubi, 2002). The idea of connected dominating set based multicasting is CDS forms a virtual backbone by which minimum number of nodes are responsible for multicasting the data in the backbone instead of all the multicast group members of the network (J. A Torkestani et al, 2010). In general, CDS can be constructed and calculated by using either global or local network information and centralized or distributed way respectively. However, due to the characteristics of wireless sensor networks, it is hard to obtain and maintain global network information also CDS calculation in a single node is not efficient (Liang, O et al, 2007). Therefore, the proposed multicasting routing protocol focuses on local information and distributed way to construct and calculation of CDS in WSN.

Shuai Wang et al, (2013) designed a new scheme, named NCDS that uses network coding over connected dominating set, to reduce energy consumption in wireless adhoc networks. Xiaoyan Kui et al (2013) proposed and investigated the problem of constructing an energy-balanced CDS based network backbone to extend the network life time in data collection. Hengzhe Li et al (2014) investigated the relation of independence number and 2-connected domination number for a WSN. Donghyun Kim et al (2009) investigated the problem of constructing quality CDS in terms of size, diameter, and Average Backbone Path Length (ABPL). Hongjie Du et al (2010) compared the size of MIS and Min WCDS in unit disk graph and also presented a distributed algorithm to construct weakly connected dominating set for secure clustering in distributed sensor network.

Zhao zhang et al (2009) introduced polynomial time approximation scheme (PTAS) for minimum CDS in WSN. Javad Akbari et al (2010) proposed three centralized learning automata-based heuristic algorithms for approximating a near optimal solution to the minimum weight Steiner connected dominating set (WSCDS) problem. Deying Li et al (2009) compared the size of MIS and Min WCDS in unit disk graph and also presented a distributed algorithm. Jeremy Blum et al (2004) discussed about CDS construction techniques proposed in the context of sensor networks and MANETs. Jie Wu and Hailan Li (1999) proposed a simple and efficient distributed algorithm for calculating connected dominating set in ad-hoc wireless networks. Yiwei Wu and Yingshu Li (2009) discussed about connected dominating set algorithms both centralized and distributed algorithm to construct CDS. Stefan and Volker T (2011) introduced and evaluated a new local, probabilistic self-stabilizing algorithm providing fault-tolerance and scalability for networks of high density.

IV. SURVEY ON RANDOM LINEAR NETWORK CODING

Multicasting with network coding was investigated quite intensively in recent years. Ahlswede et al (2000) proposed network coding in information theory to improve throughput in wireless networks and showed that network coding can achieve maximum multicast rate in the network. S.Katti et al (2008) presented the core idea of mixing packets by the XOR operation to increase the network throughput. Tracey Ho et al (2006) presented a distributed random linear network coding approach for transmission and compression of information in general multisource multicast networks. Rout, RR et al (2013) attempted to enhance the lifetime of WSN using duty cycle and NC. Zhu et al (2004) applied network coding to overlay network to improve capacity by constructing a 2-reduandant multicast graph. Dumitrescu et al (2009) proposed a layer multicast with network coding. Jaggi et al (2005) presented a polynomial time construction showing that network coding at intermediate nodes could obtain larger rates than without coding. Zhi-jie Han et al (2014) proposed a set of distributed algorithms for improving the multicast throughput in wireless sensor networks. Angelos antonopoulos et al (2012) introduced a network coding-aided energy efficient Medium Access Control (MAC) protocol which act as helpers in cooperative Automatic Repeat request-based (ARQ-based) wireless networks. Yixin Jiang et al (2009) proposed a novel dynamic-identity based signature scheme for network coding. This scheme can rapidly detect/drop the packets that are generated from pollution attacks and efficiently thwart random forgery attack.

Alireza et al (2014) explored the fundamental limitations of the benefit of network coding in multihop wireless networks and presented a lower bound on the average number of transmissions of multiple unicast sessions under any arbitrary network coding. B.T Swapna et al (2013) investigated the throughput and decoding-delay performance of random linear network coding as a function of the coding window size and the network size. Deze Zeng et al (2014) explored how the maximum throughput can be achieved in a two-way relay wireless network. Xiaoyan Wang et al (2014) proposed a novel network coding aware cooperative MAC protocol, namely NCAC-MAC, for wireless ad hoc networks. The design objective of NCAC-MAC is to increase the throughput and reduce the delay. Ching-Min Lien et al (2013) Proposed a packet scheduling algorithm and also introduced fictitious packets in the dynamic frame sizing algorithm. Muhammad AzharIqbal et al (2011) described opportunistic routing and identifies differentiation between NC-aware and NC-based routing mechanisms in wireless ad hoc networks. Jingyao Zhang et al (2008) investigated the multicast routing problem based on network coding and put forward a practical algorithm to obtain the maximum flow multicast routes in ad-hoc networks. Hongyu Han et al (2013) studied focuses on analysing the failure probabilities of random linear network coding to study its performance for multicast network, emphatically some known upper bounds of the failure probabilities have been improved and the worst cases are indicated for these bounds. R Ahlswede et al (2000) introduced a new class of problems called network information flow to characterize the admissible coding rate region, and shown their result regarded as the Max-flow Min-cut Theorem for network information flow. Rashmi R et al(2013) improved the energy efficiency of the bottleneck zone which leads to overall improvement of the network lifetime by considering a duty cycled WSN and investigated the performance metrics, namely, packet delivery ratio and packet latency. Kate Ching-Ju et al (2013) formulated a new optimization model called multirate multichannel multicast with intraflow NC (RCMNC), which solves the joint channel assignment, rate selection, and flow allocation problems for multihop intraflow NC multicast also proposed an algorithm to approximate the solution of the dual problem in polynomial time. I-Hong Hou et al (2008) proposed AdapCode: a reliable data dissemination protocol that uses adaptive network coding to reduce broadcast traffic in the process of code updates. Xing Wang et al (2011) presented an energy-efficient retransmission scheme based on network coding technique for wireless sensor networks.

V. SURVEY ON MINIMUM CONNECTED DOMINATING SET

The fundamental challenge in achieving high throughput, reliable multicast in WSNs is same as of high throughput, reliable unicast in wireless network. To achieve high throughput, reliable multicast, this work has applied classic techniques such as Minimum Connected Dominating Set (MCDS) and Random Linear Network Coding (RLNC). Combination of these two techniques can achieve both reliability and high throughput in WSN. In WSN, how to setup a small virtual backbone with high efficiency is a promising approach which is modeled as the MCDS problem.

Guha et al (1998) studied the MCDS problem and showed that this problem is NP-hard in an arbitrary undirected graph. Alzoubi et al (2002) proposed the first distributed algorithm guaranteeing a constant approximation factor for CDS construction based on MIS in UD Graph. Islam et.al provided a distributed algorithm to construct small sized connected dominating set for UD Graph. It is based on the computation of convex hull of sensor nodes which are considered as vertices. Purohit, G. N. et al (2010) proposed an algorithm to find MCDS using dominating set in UD Graphs. Islam et al (2008) provided a distributed algorithm to construct small sized connected dominating set for UD Graph. It is based on the computation of convex hull of sensor nodes which are considered as vertices. Weili Wu et al (2006), improved the algorithm for approximating the minimum connected dominating set are based on the construction of a maximal independent set in adhoc wireless networks. Zhao Zhang et al (2009) introduced a new construction algorithm named PTAS for the minimum connected dominating set in unit ball graph and improved the running time of PTAS for unit disk graph.

Donghyun Kim et al (2009) investigated the problem of constructing quality CDS in terms of size, diameter, and Average Backbone Path Length (ABPL). Mano Yadav et al (2009) presented a modified approach to determine MCDS of an underlying graph of a Wireless Adhoc network. Namsu Ahn and Sungsoo Park (2011) suggested an improved optimal algorithm for the minimum connected dominating set problem and proved it is outperformed the previous algorithms. Mallikarjun Avula et al (2012) proposed a simple, inexpensive and novel algorithm of computing a minimum CDS and showed that it is efficient in terms of both message complexity and the size of the CDS. B. Gendron et al (2014) presented a algorithm to solve the minimum connected dominating set problem in an undirected graph based on two approaches: a benders decomposition algorithm and a branch-and-cut method developed a hybrid algorithm that combines these two approaches. Weiping Shang et al (2007) proposed approximation algorithms for minimum m-connected k-dominating set problem. C.Ambuhl et al (2006) presented the constant-factor approximation algorithm for the minimum-weight dominating set problem in unit disk graphs. J.L Hurink and T.Nieberg (2007) presented the first polynomial-time approximation scheme (PTAS) for the Minimum Independent Dominating Set problem in graphs of polynomially bounded growth, which are used to characterize wireless communication networks. Jing He et al (2011) proposed a novel Genetic Algorithm (GA) to solve the reliable MCDS problem without increase the size of CDS. Fei Dai and Jie Wu (2004) proposed a dominant pruning rule to reduce the size of the dominating set in adhoc wireless networks. L.Ruan et al (2004) presented a new one-step greedy approximation for minimum connected dominating sets. M Rai et al (2009) proposed an power aware algorithm for finding MCDS using dominating set in wireless networks.

VI. SURVEY ON IDENTITY-BASED CRYPTOGRAPHY

In WSNs, Secure communication mechanisms have been widely deployed to ensure confidentiality, authenticity and integrity of the nodes and data. Gaurav Sharma et al (2012) given overview of security frameworks designed so far for WSNs. In recent years, many WSNs applications based on trusted communication to ensure large user acceptance also RLNC based applications are vulnerable to possible malicious pollution attacks in WSN. IBC have been well-recognized as the most effective approach to address this security issue. Y Jiang et al (2010) proposed a novel dynamic-identity based signature scheme for network coding by signing linear vector subspaces which can rapidly detect or drop the packets that are generated from pollution attacks and efficiently thwart random forgery attack also provided one-way identity authentication without requiring any extra secure channels or separate certificates, so that the transmission cost can be significantly reduced. For secure random linear network coding, it is prerequisite to achieve efficient message integrity and validity. The non cryptography based schemes (T.Ho et al, 2004) and (S. Jaggi et al, 2007), can only detect or filter out polluted messages at the sinks, but not at the forwarders. The basic idea in existing cryptography-based schemes is to detect each packet before it gets mixed into the buffer, including a homomorphic hash scheme (C.Gkantsidis et al, 2006), a homomorphic signature scheme (D charles et.al, 2005), and a secure random checksum scheme (C.Gkantsidis et al, 2006). These solutions either require an extra secure channel (C.Gkantsidis et al, 2006), incur high computation overhead due to not supporting batch verification (D.charles et al, 2005), suffer from relatively high extra transmission overhead (F. Zhao et al, 2007), endure weak scalability, or are vulnerable to the random forgery attack, by which an adversary may arbitrarily forge signatures for a given message if sufficient signatures of ‘‘stale” messages are collected. IBC has some weaknesses but is much easier to use than PKI. For its advocates, IBC provides a more reasonable balance between security and usability.

Y.M. Yussoff et al (2011) proposed an algorithm to confirm the trustworthiness of between sensors nodes in WSN based on the principles defined by Trusted Computing Group (TCG). L. B. Oliveira et al (2006) discussed about how the IBE can solve the key agreement problem in WSNs. R. Yasmin et al (2010) proposed an efficient and secure framework for authenticated multicast in WSN using identity based cryptography. H.K Patil et al (2011) proposed location and energy efficient routing scheme using identity-based cryptography in WSNs. Manel Boujelben et al (2011) proposed an identity based key management (IKM) scheme designed for heterogeneous sensor networks, which provides a high level of security based on public key cryptography named pairing identity based cryptography. D. Boneh and M. Franklin (2003) proposed a fully functional identity-based encryption (IBE) scheme based on bilinear maps. Yang Lijun et al (2013) proposed an Identity-Based Key Agreement Scheme (IBKAS) based on identity-based encryption and Elliptic Curve Diffie-Hellman (ECDH) to solve the problems of high memory occupation, low connectivity and poor resiliency against node capture in the large scale Wireless Sensor Networks (WSNs). IBKAS achieves significant improvement in key connectivity, communication overhead, memory occupation, and security strength, and also enables efficient secure rekeying and network expansion in large scale WSNs.

VII. CONCLUSION

WSNs hold the promise of many applications in the area of monitoring and control systems. Many properties of the environment can be observed by the monitoring system with the advent of cheap and tiny sensors. All these applications are meant for the specific purposes, and therefore maintaining data transport reliability is one of the major concern and the most important challenge. To address the reliability, we survey the various existing techniques; each of them has its own unique working to ensure the reliability. Some of the techniques use retransmission mechanism while others use redundant information for insuring the reliability.In this paper literature survey on wireless sensor network, multicast routing protocol, connected dominating set, random linear network coding, minimum connected dominating set, identity-based cryptography, real time challenges, various QoS techniques and performance metrics are reviewed. Design, deployment and functional aspects of a reliable WSN are analyzed. In this paper, we presented a comprehensive survey of various techniques to develop reliable transmission in wireless sensor networks.

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