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Network Coding in Wireless sensor Network - An Overview

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ABSTRACT

Network coding is a technique where each sensor nodes combine packets using mathematical operation, which reduces the number of broadcast packets in a wireless sensor network (WSN). Network coding methods are used to improve a network's throughput, efficiency and scalability when finding optimal solutions to the general network problems. It can also be a method for dealing with attacks and eavesdropping. However, the broadcast nature of WSN and the diversity of the links make network coding more attractive. In this paper, we survey the recent works on network coding, regarding their techniques, assumptions and applications in WSN.
Keywords: Wireless sensor networks, Network coding, Object tracking, Throughput, Reliability.

I. INTRODUCTION

Wireless sensor networks (WSN) have gained worldwide attention in recent years, particularly with the increase in Micro-Electro-Mechanical Systems (MEMS) technology which has facilitated the growth of smart sensors. These sensors are small, with limited processing and computing resources, and they are inexpensive compared to traditional sensors. These sensor nodes can sense, measure, and gather information from the environment and, based on some local decision process, they can transmit the sensed data to the user.

Smart sensor nodes are low power devices equipped with one or more sensors, a processor, memory, a power supply, a radio, and an actuator. A variety of mechanical, thermal, biological, chemical, optical, and magnetic sensors may be attached to the sensor node to measure properties of the environment. Since the sensor nodes have limited memory and are typically deployed in complicated-to-access locations, a radio is implemented for wireless communication to transfer the data to a sink [3]. The main power source of a sensor node is battery. Alternate power supply that yield power from the environment such as solar panels may be added to the node depending on the suitability of the environment where the sensor will be organized. Actuators may be integrated in the sensors, depending on the sensor's application and its types used.

A WSN consists of a number of sensor nodes working together to monitor an area to obtain data about the environment. Typically WSNs are classified in to two types they are structured and unstructured. Sensor nodes are deployed in an ad hoc manner into the field in the unstructured WSN. Once organized, the network is left unattended to perform monitoring and reporting functions. In an unstructured WSN, network protection such as managing connectivity and detecting failures is difficult since there is lot of nodes. In a structured WSN, sensor nodes are deployed in a defined manner, as shown in Figure 1. The benefits of a structured network is that fewer nodes can be deployed with lower network maintenance and management cost. Small amount of nodes can be placed at precise locations to provide coverage while ad nodes. In a structured WSN, sensor nodes are hoc deployment can have uncovered regions.

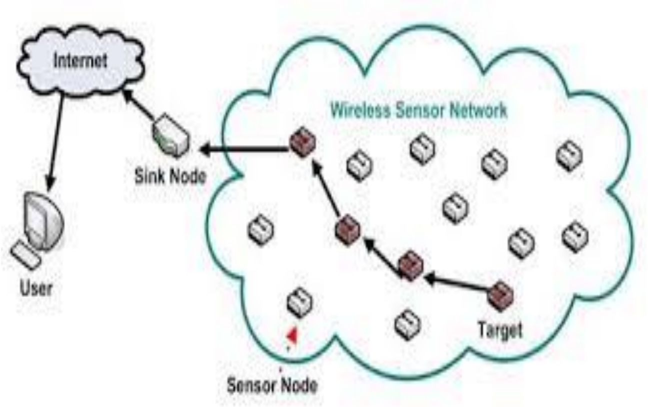

Figure 1: Sensor Node Deployment

WSNs have great potential for many applications in scenarios such as military target tracking and surveillance, natural disaster relief, biomedical health monitoring and hazardous environment exploration and seismic sensing. In military, object tracking and surveillance, a WSN can support in intrusion detection and identification. For seismic sensing, ad hoc deployment of sensors along the volcanic area can detect the development of earthquakes and eruptions.

Network coding has been shown to be an effective approach to improve the wireless sensor network system performance. However, many security issues obstruct its wide deployment in practice. Besides the attacks, there is another severe threat that of wormhole attacks, which undercut the performance gain of network coding. The impact of wormhole attacks and countermeasures are generally unidentified, due to the characteristics of network coding systems are noticeably different from traditional wireless networks.

II. METHODS AND MATERIAL

Overview of Network Coding

Network coding is an optimizing concept for improving network capability, in addition to increase throughput or reliability. Also in wireless sensor networks, network coding has been proposed as a method for improving communication.
Network Coding can also increase multicast capability from different networked circumstances which demand different traffic characteristics. Network coding for data dissemination can increase reliability and it is harder to apply network coding for converge cast, probably the most important traffic paradigm in WSN, where data is collected from multiple sources and transported to one or more data sinks. Below we review a number of network coding algorithms for improving the throughput.

Distributed detection Algorithm against Wormhole in wireless Network (DAWN)

This algorithm quantifies wormholes devastating harmful impact on network coding system performance through experiments. DAWN explore the change of the flow directions of the innovative packets caused by wormholes. Rigorously prove that DAWN guarantees a good lower bound of successful detection rate and the perform analysis shows on the resistance of DAWN against collision attacks [1]. It is to be found that the robustness depends on the node density in the network and prove a necessary condition to achieve collision-resistance. DAWN does not depend on any location information, global synchronization assumption or particular hardware/middleware. Extensive experimental results have verified the effectiveness and the efficiency of DAWN.

Distance-based Secure Network Coding (DSNC)

To provide a high-security guarantee to network coding and lower the computing complexity induced by signature scheme, full advantage of homomorphism property was considered to build lattice signature schemes and secure network coding algorithms. Initially, by means of the distance between the message and its signature in a lattice and proposed a Distance-based Secure Network Coding (DSNC) algorithm and stipulate its security to a new hard problem Fixed Length Vector Problem (FLVP), which is harder than Shortest Vector Problem (SVP) on lattices [2]. Secondly, considering the boundary on the distance between the message and its signature. An efficient Boundary-based Secure Network Coding (BSNC) algorithm was proposed to reduce the computing complexity tempted by square calculation in DSNC. Results show that the proposed signature schemes have stronger enforceability due to the natural property of lattices than traditional Rivest-Shamir-Adleman (RSA)-based signature scheme.

Centrality-based Network Coding Node Selection (CNCNS)

The problem of minimizing the number of coding nodes is caused by network coding overhead and is proved to be NP-hard. To resolve this issue, Centrality-based Network Coding Node Selection (CNCNS) was used as a heuristic and distributed mechanism to minimize the number of network coding (NC) nodes without compromising the achievable network throughput. It repeatedly analyses the node centrality and selects NC node in the precise area. Since it operates with distributed manner, and it can dynamically adjust the network status with approximately minimizing network coding nodes [4]. Especially, CNCNS adjusts the network performance of network throughput and reliability using control indicator. Results shows that the well selected network coding nodes can improve the network throughput and almost close to throughput performance of a system where all network nodes operate network coding.

Peer-To-Peer Multicast System

Network coding is a promising enhancement of routing to advance network throughput and provide elevated reliability. This system allows a node to produce output messages by encoding its received messages. There are two reasons to make Peer-to-peer network to apply network coding: the topology of a peer-to-peer network is built arbitrarily, thus it is simple to adapt the topology to facilitate network coding; the nodes in a peer-to-peer network are end hosts which can perform more complex operations such as decoding and encoding than simply storing and forwarding messages. A scheme has been proposed to apply network coding to peer-to-peer file sharing which employs a peer-to-peer network to distribute files resided in a web server or a file server. This scheme exploits a special type of network topology called combination network, which can achieve unbounded network coding gain measured by the ratio of network throughput with network coding to that without network coding [5]. This scheme encodes a file into multiple messages and divides peers into multiple groups with each group responsible for relaying one of the messages. To satisfy the property that any subset of the messages can be used to decode the original file as long as the size of the subset is sufficiently large. To meet this requirement, first define a deterministic linear network coding scheme which satisfies the preferred property, then attach peers in the same group to flood the corresponding message and connect peers in different groups to distribute messages for decoding. Moreover, this scheme can be readily extended to support link heterogeneity and topology awareness to further improve system performance in terms of throughput, reliability and link stress. Results shows that the new scheme can achieve 15%-20% higher throughput than another peer-to-peer multicast system

Intra-session network coding

It has been shown to offer significant gains in terms of achievable throughput and delay in settings where one source multicasts data to several clients. Here considered a more general scenario where multiple sources transmit data to sets of clients over a wire line overlay network and proposed a novel framework for efficient rate allocation in networks where intermediate network nodes have the opportunity to combine packets from different sources using randomized network coding [6]. The minimization of the average decoding delay in the client population and solve it with a gradient-based stochastic algorithm was formulated. The Optimized inter-session network coding solution is evaluated in different network topologies and is compared with basic intra-session network coding solutions. Results shows that the benefits of proper coding decisions and effective rate allocation for lowering the decoding delay when the network is used by concurrent multicast sessions.

Algebric Coding

Network coding encourages information coding across a network. Since the need, benefit and complexity of network coding are sensitive to the underlying graph structure of a network, existing theory on network coding frequently treats the network topology as a black box, hub on algebraic or information theoretic aspects of the problem. Here in-depth examination of the relation between algebraic coding and network topologies were proposed [7]. In particular, first formulate NC-minor conjectures that articulate such a connection between graph theory and network coding, in the language of graph minors. Next prove that the NC-minor conjecture for multicasting two information flows is almost equivalent to the Hadwiger conjecture, that tie graph minors with graph coloring. Finally prove that, for the general case of multicasting random number of flows, network coding can make diversity from routing only if the network contains a minor, and this minor containment result is tense.

Broadcast Incremental Power (BIP) algorithm

In an ad-hoc wireless network, all the nodes want to transmit information to all other nodes. The energy efficiency is one of the performances metric for defining the factor for wireless networks as it directly concerns the battery life and thus network longevity. It shows that the benefits network coding has to offer in a wireless ad-hoc network as far as energy-savings is concerned compared to the store-and-forward strategy [8]. Network coded broadcasting concentrates on reducing the number of transmissions performed by each forwarding node in the end to end broadcast application, where all forwarding node merges the incoming messages for transmission. Using network coding the total number of transmissions can be reduced, when compared to broadcasting using the same forwarding nodes without coding. Finally the performance of a network coding-based Broadcast Incremental Power (BIP) algorithm for all-to-all broadcast was presented. Results show that optimization using network coding method lead to substantial improvement in the cost associated with BIP

Network coding cliques (NCC)

Network coding has shown the promise of significant throughput improvement. The maximum network throughput using network coding was achieved in a two-way relay wireless network [9]. To efficiently utilize the coding opportunities, the concept of network coding cliques (NCCs), upon which a formal analysis on the network throughput using network coding is elaborated. In particular, the closed-form expression of the network throughput under certain traffic load in a slotted ALOHA network with basic medium access control was derived. Furthermore, the maximum throughput as well as optimal medium access probability at each node under various network settings was carried out.

Multiple access relay channel (MARC)

Network coding is a paradigm for modern communication networks by allowing intermediate nodes to mix messages received from multiple sources. Under the same transmission time slots constraint, several different transmission strategies applicable to the system model, together with direct transmission, decode and forward, digital network coding with space time coding. An Analog network coding was investigated and compares the error rate performance using multiple access relay channel (MARC) with multiple antenna relay [10]. Results show that in the system model under examination, these schemes with network coding do not show any performance gain compared with the traditional schemes with same time slots consumption.

III. RESULTS AND DISCUSSION

Distributed Coordination Function (DCF)

It may reduce the potential of network coding in 802.11 wireless networks. Appropriate to the randomness of DCF, the coding delay, distinct as the time that a packet must wait for a coding opportunity, may enhance and corrupt the network performance [11]. The TCP traffic increases, the coding opportunities rise up to 70% and the coding delay increases significantly. Simulation results show that the coding delay may be reduced with these methods using at the same time an estimation threshold. It will increase the estimation's mean in order to exploit a high percentage of the coding opportunities.

The use of iterative message passing-based decoding for the described network coding scenario, as the main contribution, motivated by Bayesian compressed sensing. The possibility of approximate decoding, even with fewer received measurements (packets) than the number of messages [12]. As a result, real field network coding scenario, called quantized network coding, is proficient of inter-node compression without the need to know the internodes redundancy of messages. Also presented numerical and analytic arguments on the robustness and computational simplicity for the quantized network coding.

Network bandwidth is a performance concern especially for collective communication because the bisection bandwidth of recent supercomputers is far less than their full bisection bandwidth [13]. In this context to exploit the use of a network coding technique to reduce the number of unicasts and the size of transferred data generated by latency-sensitive collective communication in supercomputers was proposed. This network coding scheme has a hierarchical multicasting structure with intra-group and inter-group unicasts [14]. Quantitative analysis show that the aggregate path hop counts by hierarchical network coding decrease as much as 94% when compared to conventional unicast-based multicasts.

IV. CONCLUSION

In this paper, we survey the recent works on network coding, regarding their 1) techniques, 2) algorithms 3) assumptions 5) network services and applications in WSN. We have summarized different proposed designs, algorithms, and services. There are still many issues to be resolved around network coding such as communication architectures, security, and management. By solving these issues, we can shut the gap between technology and application.

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