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An Overview of Data Dissemination in Wireless Sensor Network Using an Instantly Decodeable Network Coding

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Wireless Sensor Networks (WSNs) are networks of small, cheap, independent battery-powered sensor nodes, finds applications in agriculture, health care, intrusion detection, asset tracking, habitat monitoring and in many other fields.

It is sometimes necessary to disseminate data via wireless links after the deployment of sensors so as achieve the objectives of sensors configurations parameters adjustment or distribution of commands management and queries to sensors. The present study considered how Shortest Path Minded Sensor Protocols for Information via Negotiation (**S**PIN)-Recursive (SPMS-Rec), reduces the energy dissipated in the event of failures by requiring intermediate relay nodes to try alternate routes, is suitable for data dissemination. Despite to the power constraints and memory limitations of sensory nodes, 'Instantly Decodable Network coding' (IDNC) was considered because of its practicality, relevance and numerous desirable properties such as instant packet recovery, simple XOR-based packet encoding and decoding, and zero buffer memory to store un-decoded packets. The paper concludes with reference and suggestions of possible future research areas.

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Keywords: Wireless sensor networks; sensor node; sink; data dissemination; instantly decodable network coding.

1. INTRODUCTION

Wireless Sensor Networks (WSNs) are networks of small, cheap, spatially distributed autonomous independent battery-powered sensor nodes. These nodes consist of a microcontroller and a radio for communication, as well as one or more sensors. When deployed in large numbers (say hundreds or even thousands), sensor nodes offers a fine monitoring capability, which can find useful applications in agriculture, intrusion detection, asset(s) tracking, as well as in many other fields of human endeavors. As the name implies, 'wireless sensor networks' WSNs employ wireless communication to achieve its goal [1]. One major component used in this network of sensors is a special technical component that helps to monitor the sensor's health and the health of neighboring sensors. Although the health messages are not too critical to the correct applications execution, their use is viewed more as preventive maintenance. Health messages are usually seldom sent or sent rather infrequently (about once per hour or less dependent on the duty cycle) with no guarantee on their delivery [2].

Wireless Sensor Networks (WSN) is intended for monitoring the physical or environmental conditions. The necessary requirement of a wireless sensor node is to sense and collect the data from a certain domain, process it and transmit it to the sink where the application is localized (Uge, 2018). However, if the direct communication between a sensor and the sink is left uncontrolled or untamed, this may force nodes to emit their messages with such a high power that their resources could become quickly depleted. Hence, the collaboration of nodes to ensure that distant nodes communicate with the sink becomes a critical requirement for the study. This understanding underscores the need for the incorporation of intermediate node or nodes which facilitate to propagate messages thus making sure that a route with multiple links or hops to the sink is established. Taking into cognizance the reduced capabilities of sensors, the communications with the sink could be initially conceived without a routing protocol. With this premise, the flooding algorithm stands out as the simplest solution. In this algorithm, the transmitter broadcasts the data, which are consecutively retransmitted via several intermediate nodes in order to ensure their arrival at the intended destination. However, its simplicity brings about significant drawbacks. Firstly, an implosion (which is a violent inward collapse of a structure or system due to pressure imbalance) is detected because nodes redundantly receive multiple copies of the same data message. Additionally, these anomalies may be detected by several nodes in the affected area; therefore, multiple data messages containing similar information are introduced into the network. Moreover, these irregularities significantly gain further momentum when consider the fact that the nodes did not take into account their resources to limit their functionalities. One optimization relies on the gossiping algorithm. Gossiping algorithms helps to avoids implosion as the sensor transmits the message to a selected neighbor instead of broadcasting to all its neighbors as in the classical flooding algorithm. However, overlap and resource blindness are still not eliminated. Furthermore, these inconveniences are further highlighted as the number of nodes in the network increases. Due to the deficiencies and loopholes of the previous strategies, routing protocols become necessary in wireless sensor networks.

Nevertheless, it must be made abundantly clear that the inclusion of a routing protocol in a wireless sensor network constitutes a very arduous task. One of the major limitations is in the nodes identification. Since wireless sensor networks are of potentially unique identifier such as the MAC (Medium Access Control) address or the GPS coordinates is not recommended as it forces a significant payload in the messages [3]. However, this drawback is easily overcome in wireless sensor networks since an IP address is not a requirement to identifying the destination node of a specific packet. In fact, attribute-based addressing fits better with the specificities of wireless sensor networks [3]. In this case, an attribute such as node location and sensor type is used to identify the final destination. Once nodes are identified, routing protocols are in charge of constructing and maintaining routes between distant nodes.

The rest of this paper is organized as follows: in Section 2, we give an overview of relevant research in the area of wireless sensor network, data dissemination protocol and instantly decodable network coding. In Section 3, we discuss the design constraints for routing in wireless sensor, followed by the description of data dissemination protocol used in this paper in Section 4. In Section 5, we discuss instantly decodable network cording for WSNs. Finally, in Section 6 we present our conclusions.

2. RELATED WORK

Farhan Simjee and Pai H. Chou, describe a super capacitor-operated, solar-powered wireless sensor node called Everlast. Unlike traditional wireless sensors that store energy in batteries, Everlast's use of supercapacitors enables the system to operate for an estimated lifetime of 20 years without any maintenance. The newness or originality of this system lies in the feed forward, PFM (pulse frequency modulated) converter and open-circuit solar voltage method for maximum power point tracking, enabling the solar cell to efficiently charge the super capacitor and power the node. Experimental results show that Everlast can achieve low power consumption, long operational lifetime, and high transmission rates [4].

Gunjan Khanna et al. propose a protocol called Shortest Path Minded SPIN (SPMS) in which every node has a zone defined by its maximum transmission radius. A data source node advertises the availability of data to all the nodes in its zone. Any interested node requests the data and helps to send the data using multi-hop communication via the shortest path. The failure of any node in the path is detected and recovered using backup routes. The protocol called SPIN (Sensor Protocols for Information via Negotiation) [5,6] sprang from the idea that a sensor node should handshake or interacts with its neighbors and decide on the data that it already has and the data that it needs to obtain before initiating the operation to get the data. Nodes in SPIN label their data using high-level data descriptors called *meta-data* and use meta-data negotiation to determine if a node needs the data and therefore eliminates redundant transmissions. In this paper, we propose a protocol called SPMS (Shortest Path Minded SPIN) owing to its many advantages such as the reduction of the energy consumption and the end-to-end delay of SPIN. We achieve this by using the fact that sensor nodes can operate at multiple power levels and once negotiation of meta-data is initiated, the remainder of the protocol and the data transfer can occur in multiple hops using the lowest energy level. SPMS is resilient to node and link failures since the data is exchanged through intermediate nodes and it has the option of cache of data to tolerate failures of the source or another intermediate node [7].

Anh Le et al. considered the scenario of broadcasting for real time applications and loss recovery via instantly decodable network coding. First, we prove that this problem is NP-Hardin the general case. Then we consider the practical probabilistic scenario, where users have the i.d. loss probability and the number of packets is linear or polynomial in the number of users, and we provide a polynomial-time (in the number of users) algorithm that finds the optimal coded packet. Simulation results show that the proposed coding scheme significantly outperforms an optimal repetition code and a COPE-like greedy scheme [8].

Lei Yang et al. attributed the adaptive NC schemes in a realistic wireless emulation environment with real radio transmissions. As illustrated in Fig.3, the testbed platform is made up of four main parts: radio frequency network emulator simulator tool, RFnest^{TM} (developed and owned as a trademark by Intelligent Automation, Inc.), software simulator running higher-layer protocols on a PC host, configurable RF frontends (Router Station Pro from Ubiquiti), and digital switch. They removed the radio antennas and connected the radios with RF cables over an attenuator box. Then, real signals are dispatched over emulated channels, where actual physical-layer interactions takes place between radios, and in the meantime the physical channel attenuation is digitally controlled based on the simulation model or recorded field test scenarios can be replayed [9].

3. DESIGN CONSTRAINTS FOR ROUTING IN WIRELESS SENSOR NETWORKS

One of the main design goals of WSNs is to carry out data communication while trying to prolong the lifetime of the network and prevent connectivity degradation by employing aggressive energy management techniques. Due to the reduced computing, radio and battery resources of sensors and limited bandwidth of the wireless links connecting sensor nodes, routing protocols in wireless sensor networks are expected to fulfill the following requirements:

3.1 Autonomy

The assumption of a dedicated unit that ensures that the radio and routing resources do not stand in the way of wireless sensor networks as it could be an easy point of attack. Since there will not be any centralized entity to make the routing decision, the routing procedures are transferred to the network nodes.

3.2 Energy Efficiency

Routing protocols should prolong network lifetime while maintaining a good quality of connectivity in order to ensure the communication between nodes. It is important to note that the routine battery replacement in the sensors is not feasible since most of the sensors are randomly placed. Added to that is a consideration of the fact that some devices are buried to make them able to sense the soil.

3.3 Scalability

Wireless sensor networks are composed of hundreds of nodes so routing protocols should function and work with this amount of nodes.

3.4 Resilience

No mechanical or electrical device or devices are perfect, as such even sensors may unpredictably stop operating due to environmental reasons or due to overwhelming power consumption from the battery. Hence, routing protocols should be able to cope with this eventuality such that when a current-in-use node fails, an alternative route could be discovered to complete the task of data dissemination.

3.5 Device Heterogeneity

Although most of the civil applications of wireless sensor network rely on homogenous nodes (use of the same type of sensors), the introduction of different kinds of sensors could report significant benefits. The use of nodes with different processors, transceivers, power units or sensing components may undoubtedly improve the characteristics of the network. Among others, the scalability of the network, the energy drainage or the bandwidth all benefit from the nodes heterogeneity.

3.6 Mobility Adaptability

The different applications of wireless sensor networks could demand that each node copes with its own mobility, the mobility of the sink or the mobility of the event to sense. Routing protocols should provide appropriate supports for these movements. This is not to say that the routing protocols are shielded from all challenges that beset all other protocols. Consider for instance other significant routing challenges and design issues that affect even the routing processes in WSNs, these are: Node deployment, Energy consumption without losing accuracy, Data reporting method, Fault tolerance, Network dynamics, Transmission media, Connectivity, Coverage, Data aggregation, Quality of service [3,10].

An alternative approach to prolong network lifetime by preserving network connectivity is to deploy a small number of costly, but more powerful, relay nodes whose main task is to communicate or handshake with other sensors or relay nodes [11].

WSN nodes are typically organized in one of three types of network topologies. The three possible topologies in common use are: *Star topology*, where ‘each node connects directly to a gateway’ or *Cluster tree network topology,* where ‘each node connects to a node higher in the tree and then to the gateway, this connection ensures that data is routed from the lowest node on the tree to the gateway’. Finally, to offer increased reliability, the third type of nodes organization i.e. the *Mesh networks topology* features nodes that are capable of connecting to multiple nodes in the system and transmit data through the most reliable path available at any instant of time [12]. Figs. 1 and 2 shows common WSNs topologies.

While it is a known fact that sensor network deployment is becoming more commonplace in environmental, business, and military applications, however, security of these networks poses a serious and critical concern. Without proper security, it is impossible to completely trust the genuineness or authenticity of results reported from sensor networks deployed outside of controlled environments. Interestingly, this disturbing concern can, to a reasonable degree be mitigated with the use of appropriate hardware and software application programs. Notable among these is a version of the Atmel processor with the on-chip debugging feature on/off switch in software rather than hardware would eliminate a category of possible attacks. Another possible solution would be to use location awareness applications that could detect movements on a fine scale, or use GPS, or group communication techniques. The network could then mark ‘moved’ nodes as possibly compromised and flags their data at the end-user application. Note that any such flagged data will be treated as unreliable and untrusted. Finally, if a node can be made sensitive enough to detect its own movement by the use of either accelerometers or GPS, then it can proactively delete important information stored in SRAM, flash, or anywhere else on the system as a preventative measure [13].

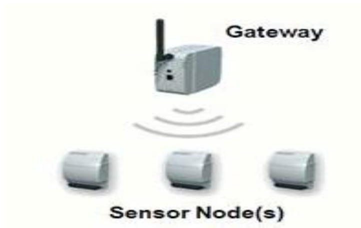

Fig. 1. WSN components, gateway, and distributed nodes

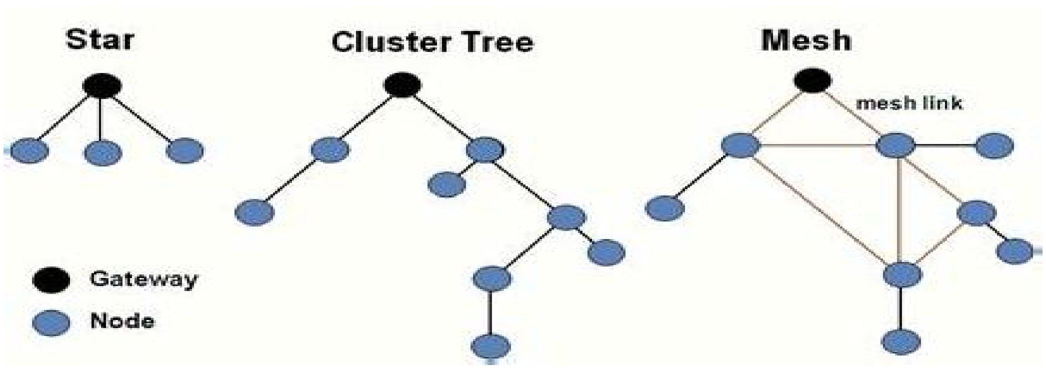

Fig. 2. Common WSN topologies

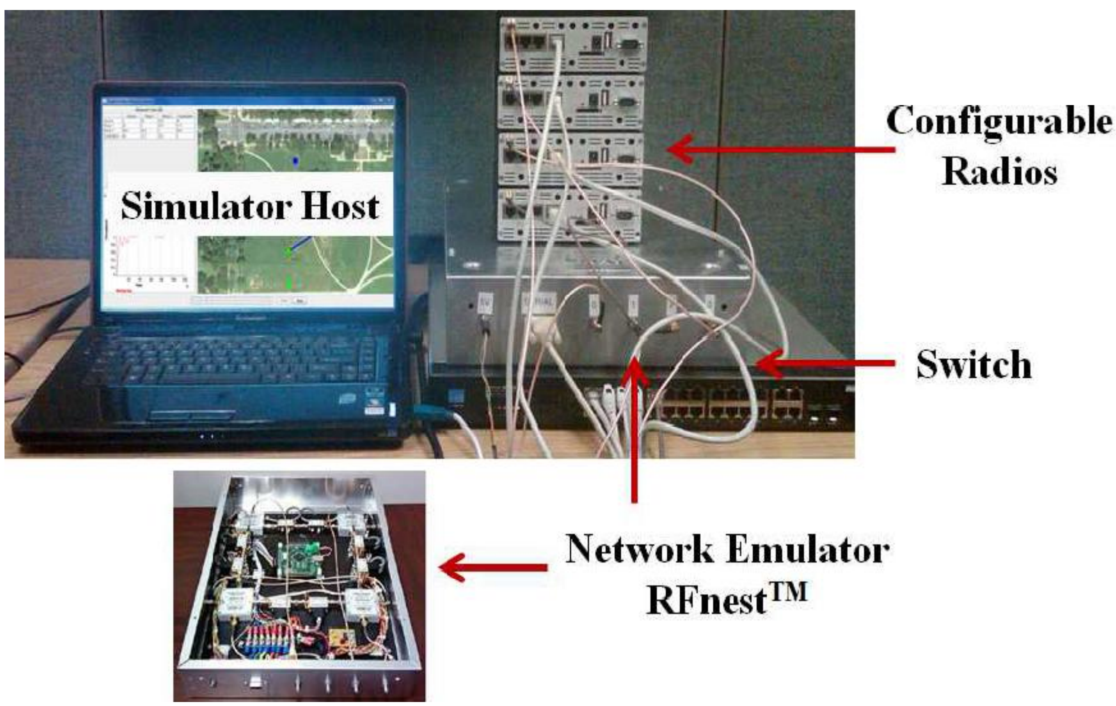

Fig. 3. Programmable RFnest™ testbed

4. DATA DISSEMINATION PROTOCOL

As sensor networks are increasingly getting used in various applications which require collection and analysis of data. Data dissemination is an important part of any sensor network. Our starting point is a recently proposed SPIN-based protocol, called Shortest-Path Minded SPIN (SPMS), in which meta-data negotiations take place prior to data exchange in order to minimize the number of data transmissions.

We propose a redesign of SPMS, called SPMS-Rec (SPMS-Recursive), which reduces the energy expended in the event of failures by requiring intermediate relay nodes to try alternate routes. The results of the simulation carried out by Sameh and Shahrokh [14] show that SPMS-Rec outperforms SPMS, and thus SPIN, yielding energy savings while reducing the delay when multiple nodes fail along a route. We further propose a modification to SPMS-Rec through request suppression which helps in reducing redundant data transmissions.

Data dissemination protocols have to face several challenges due to the unique characteristics of sensory networks. Sensor nodes are mainly battery operated and it is often infeasible to recharge or replace the batteries, especially when they are placed in hostile terrains [3]. Thus, data dissemination protocols have to be energy efficient, consuming the least amount of energy as possible. The data dissemination has to achieve a certain minimum level of reliability to be useful. Reliability can suffer due to many reasons; including the fact that communication is over a shared wireless channel. Various fading effects and shared channel are some factors causing packet loss. Protocols which do collision avoidance (e.g. CSMA-CA protocols) may not be feasible to be used in sensor networks due to limited resources. Thus, the data dissemination protocol must be tolerant to such failures caused by fading, collisions, and node failures [14].

5. INSTANTLY DECODABLE NETWORK CODING

The work of WSNs is never complete without data collection, as this is the primary task of a wireless sensor network. To this end, the sensed data has to be either transmitted to the sink node(s) or be stored within the network in the event that no sink node is currently available. Due to the power and memory constraints of the sensor nodes, it becomes very critical to do this as efficiently as possible. Over the course of this treatise, it has been made abundantly clear that 'Network coding' essentially serves to provide significant benefits in a network or system of networks. Moreover, it must be stated that significant performance improvements to sensor network protocols can be recorded by '*storing and disseminating coded information instead of the original data dissemination'*. Such methods reduce the risk of replication of some data at many nodes, while other data may be very scarce. This is of particular importance for data persistence in sensor networks [15].

Two trends of network coding were discussed in [16], namely random (or full) network coding (RNC) and opportunistic network coding (ONC). Network coding (NC) has shown great capabilities to substantially improve transmission efficiency, throughput and delay over broadcast erasure channels [17,18]. In [19,20,21], an important sub-class of the opportunistic NC was discussed, namely; the *instantly decodable network coding (IDNC)*, whereby received packets are allowed to be decoded only at their reception instant and cannot be stored for future decoding.

Although it has to be admitted that IDNC has its drawbacks and limitations, it was duly given attention to in these works owing to its practicality and numerous desirable properties, such as instant packet recovery, simple XOR-based packet encoding and decoding, and it's having no additional buffer to store un-decoded packets. As can be observed from its definition, "the sender must select a network coded packet combination in each transmission, such that a selected subset of the receivers (or all of them if possible) can decode anew source packet once they receive this coded packet".

Another important tool invaluable to the instantly decodable network coding is the *IDNC graph.* One prominent function of the IDNC graph is that it helps in the selection of the appropriate packet combinations, which are instantly decodable at specific sets or all the receivers [19,22,20,21,23]. The problem of minimizing the completion delay for IDNC was considered in many researchers [22,20] for wireless networks with erasure channels on the forward links from the sender to the receivers. This problem was formulated as a stochastic shortest path (SSP) problem, which turned out to be very complex to solve in real-time.

Notwithstanding, in order to minimize completion delays in IDNC, it is crucial to employ the analysis of the properties and structure of this SSP so as to be able to design simple maximum weight clique search algorithms. The designed algorithms were shown to almost achieve the optimal completion delay in wireless multicast and broadcast scenarios [24].

The instantly (instantaneously) decodable network coding (IDNC) is attractive owing to the following obvious merits:

1) It allows for fast decoding of packets at the receivers end, a property that is significant and of great importance to applications requiring progressively refined input, without long delays.
2) It allows for a simple XOR decoding at the receivers, thus eliminating the need for computationally expensive matrix inversions at the receivers.
3) It does not require any buffer(s) for the storage of non-instantly decodable packets for future decoding possibilities [25].

6. CONCLUSIONS

In this paper, we have considered the various applications of wireless senor networks, design constraints for routing in wireless sensor networks, the attractiveness, benefits and constraints of using SPMS-Rec for data dissemination and why Instantly Decodable Network Coding is attractive for encoding and decoding of data packets. In future work, we aim at a better way to secure our networks so that we can further trust any information emanating from sensor networks.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Halkes GP, Langendoen KG. Experimental evaluation of simulation abstractions forwireless sensor network MAC protocols. Faculty of Electrical Engineering, Mathematics and Computer Science, Delft University of Technology, 2600 AA Delft, The Netherland; 2010.
2. Alan Mainwaring, Joseph Polastre, Robert Szewczyk, David Culler, John Anderson. Wireless Sensor Networks for Habitat Monitoring; 2002.
3. Luis Javier García Villalba, Ana Lucila Sandoval Orozco, Alicia Triviño Cabrera, Cláudia Jacy Barenco Abbas. Routing protocols in wireless sensor networks. Group of Analysis, Security and Systems (GASS), Department of Software Engineering and Artificial Intelligence, School of Computer Science, Office 431, Complutense University of Madrid (UCM), Calle Profesor José García Santesmases s/n, Ciudad Universitaria, 28040 Madrid, Spain; 2009.
4. Gunjan Khanna, Saurabh Bagchi, Yu-Sung Wu. Fault tolerant energy aware data dissemination protocol in sensor networks. Dependable Computing Systems Lab School of Electrical & Computer Engineering, Purdue University 465 Northwestern Avenue, West Lafayette, IN 47907; 2003.
5. Heinzelman WR, Kulik J, Balakrishnan H. Adaptive protocol for information dissemina-tion in wireless sensor networks. Mobicom; 1999.
6. Lei Yang, Yalin Evren Sagduyu, Jason Hongjun Li, Junshan Zhang. Adaptive network coding for scheduling real-time traffic with hard deadlines. School of ECEE Arizona State University, Tempe, AZ 85287, USA Intelligent Automation, Inc., Rockville, MD 20855, USA; 2012.
7. Ravish Khosla, Xuan Zhong, Gunjan Khanna, Saurabh Bagchi, Edward J. Coyle. Performance comparison of spin based push-pull protocols. School of Electrical and Computer Engineering, Purdue University, West Lafayette, Indiana 47907.
8. Ahmed Douik, Sameh Sorour, Mohamed-Slim Alouini, Tareq Y. Al-Naffouri. Delay Reduction in Lossy Intermittent Feedback for Generalized Instantly Decodable Network Coding. King Abdullah University of Science and Technology (KAUST), Kingdom of Saudi Arabia King Fahd University of Petroleum and Minerals (KFUPM), Kingdom of Saudi Arabia; 2013.
9. Uge SU. Review on routing optimization techniques in WSN using distance vector routing protocol approach. International Conference on Emanations in Modern Engineering Science & Management (ICEMESM-2018). 2018;1-5.
10. Jamal N. Al-Karaki, Ahmed E. Kamal. Routing techniques in wireless sensor

networks: A survey. The Hashemite University and Lowa State University; 2004.
11. Errol L. Lloyd, Guoliang Xue. Relay node placement in wireless sensor networks. Senior Member, IEEE, Wireless Sensor Network; 2016.
12. Carl Hartung, James Balasalle, Richard Han. Node compromise in sensor networks: The need for secure systems. Department of Computer Science University of Colorado; 2005.
13. Farhan Simjee, Pai H. Chou. Everlast: Longlife, supercapacitor operated wireless sensor node. Center for Embedded Computer Systems, University of California, Irvine; 2006.
14. Sameh Sorour, Shahrokh Valaee. Completion delay minimization for instantly decodable network code. Student Member, IEEE and Senior Member, IEEE; 2012.
15. Anh Le, Arash S. Tehrani, Alexandros G. Dimakis, Athina Markopoulou. Instantly decodable network codes for real-time applications. University of California, Irvine, University of Southern California, University of Texas, Austin; 2013.
16. Sameh Sorour, Ahmed Douik, Shahrokh Valaee, Tareq Y. Al-Naffouri, Mohamed-Slim Alouini. Partially blind instantly decodable network codes for Lossy feedback environment. Member, IEEE, Student Member, IEEE, Senior Member, IEEE, Senior Member, IEEE, Fellow, IEEE; 2013.
17. Nguyen D, Nguyen T. Network coding-based wireless media transmission using POMDP. Packet Video Workshop (PV'09); 2009.
18. Sorour S, Valaee S. On minimizing broadcast completion delay for instantly decodable network coding. IEEE International Conference on Communications (ICC'10); 2010.
19. Sorour S, Valaee S. Completion delay minimization for instantly decodable network codes. Submitted to IEEE/ACM Transactions on Networking.
Available:http://arxiv.org/submit/402828/view
20. Zhan C, Lee V, Wang J, Xu Y. Coding-based data broadcast scheduling in on-demand broadcast. IEEE Transactions on Wireless Communications; 2011.
21. Sorour S, Valaee S. Adaptive network coded retransmission scheme for wireless multicast. IEEE International Symposium on Information; 2009.
22. Sundararajan J, Shah D, Medard M. Online network coding for optimal throughput and delay - The three-receiver case. International Symposium on Information Theory and Its Applications (ISITA'08); 2008.
23. Kulik J, Heinzelman W, Balakrishnan H. Negotiation based protocols for disseminating information in wireless sensor networks. ACM Wireless Networks. 2002;8.
24. Daniele Munaretto, Jorg Widmer, Michele Rossi, Michele Zorzi. Resilient coding algorithms for sensor network data persistence. DoCoMo Euro-Labs, Landsberger Strasse 312 – 80687 Munich, Germany DEI, University of Padova, via Gradenigo 6/B – 35131 Padova, Italy.
25. Sorour S, Valaee S. Minimum broadcast decoding delay for generalized instantly decodable network coding. IEEE Global Telecommunications Conference (GLOBECOM'10); 2010.

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