ISSN 2348-1196 (print)
International Journal of Computer Science and Information Technology Research ISSN 2348-120X (online)
Vol. 3, Issue 2, pp: (592-599), Month: April - June 2015, Available at: www.researchpublish.com

Reactive Routing Enhancement for Industrial Wireless Sensor Networks: A Review

[1]Miss.Ashvini D.Tarar, [2]Dr.M.S.Ali

[1]M.E. (CSE) II Year, Prof. Ram Meghe College of Engineering & Management Amravati, India
[2]Principal, Prof. Ram Meghe College of Engineering & Management, Amravati, India

Abstract: **In recent year Wireless sensor Network (WSN) are replacing the traditional industrial wired communication system. One of the major technical challenges in WSN is to provide reliable as well as efficient communication under fading channel. When IWSNs are deployed in a harsh industrial environment, the vulnerability of wireless signal leads to high risk of transmission failure which result in missing or delaying of process or control data. But in most existing solutions the traditional routing protocols, such as AODV, AOMDV, and DSR, may provide solution in the form of reliable protocol but these protocol suffer from less security and Denial of service. These solutions may find their limitations in industrial installations due to the harsh environmental conditions, interference issues, and other constraints which results in undesirable delay as well as additional energy consumption. To overcome these limitations new biased back off scheme is introduced in the route discovery phase to find a robust virtual guide path with low overhead which can provide more cooperative forwarding opportunities. Again, this motivates to provide better solution for above problem there is another protocol which extends AODV with R3E to increase its effectiveness and feasibility. The goal is to provide reliable reactive routing enhancement to increase the link dynamics for WSN and to increase reliable and energy efficient packet delivery against unreliable wireless link.. And provide solution to reliable route discovery and efficient cooperative forwarding problems which can effectively improve robustness, end-to-end energy efficiency, and latency. Simulation results showed that, as compared with other protocolsAODV-R3E can effectively improve robustness, end-to-end energy efficiency and latency. Now days AODV-R3E has worldwide attention for use in different applications.**

Keywords: **Industrial wireless sensor networks (IWSNs), unreliable wireless links, Ad-hoc Networking, Opportunistic routing.**

1. INTRODUCTION

A WSN can be defined as a network of devices, denoted as nodes, which can sense the environment and communicate the information gathered from the monitored field (e.g., an area or volume) through wireless links.

In Industrial wireless systems Sensor node are scattered and must transmit information over distances that can range from six inches to fifty miles, depending upon the application these sensor nodes are small in size and communicate unrestrictedly over short distances. Sensor nodes are embedded to sense the surroundings, communicate wirelessly, perform collaborative signal processing and make the environment intelligent. In WSN Sensor nodes are scattered. Sensor node consists of radio transceiver along with antenna for communication. The traditional routing protocol such an AODV [3], AOMDV [4], and DSR [5] may find their limitation in industrial installation due to the harsh environmental conditions, interference issues, and other constraints which result in undesirable delay as well as additional Energy consumption.

Wireless sensor system made revolutionary progress in industrial processing and help industry to meet the demands in today's increased competitiveness. Intelligent wireless sensors built for ubiquitous use in industrial environments [8]. Reliable reactive routing is designed to enhance existing reactive routing protocol to provide reliable and energy efficient

packet delivery against the unreliable wireless links. And specifically, introduce a biased back off scheme during the route discovery phase to find a robust guide path, which can provide more cooperative forwarding opportunities. AODV protocol extends with R3E to demonstrate effectiveness and feasibility. So ,new protocolAODV-R3E can effectively improve robustness, end-to-end energy efficiency and latency. And provide solution to reliable route discovery and efficient cooperative forwarding problems.

2. MOTIVATION

When wireless sensor technology are deployed in a harsh industrial environment the vulnerability of wireless signal leads to high risk of transmission failure and then result in missing or delaying of process or control data. The traditional routing protocol provides solutions up to some extent. The traditional routing protocol such an AODV [3], AOMDV [4], and DSR [5] may find their limitation in industrial installation due to the harsh environmental conditions, which result in undesirable delay as well as additional energy consumption. This motivates to provide better solution for reliable route discovery and efficient cooperative forwarding problems.

R3E is design to augment existing reactive routing protocol to combat the channel variation by utilizing the local path diversity in the link layer. Again R3E is designed to enhance existing reactive routing protocol to provide reliable and energy efficient packet delivery against unreliable wireless links. So, here AODV protocol extended with R3E.This new protocols AODV-R3E can effectively improve robustness, end-to-end energy efficiency and latency in IWSN.

3. LITERATURE SURVEY

Now a day's wireless sensor technology will be the obvious choice for monitoring and controlling industrial processes to optimize resource efficiency and productivity. But at the same time they must resolve the following key issues regarding technology, collaboration, culture, regulation and cost [8]. Vulnerability of wireless signal leads to high risk of transmission failure and then result in missing or delaying of process or control data. To provide reliable and efficient communication in IWSN is a challenging problem for WSN. This problem has been extensively studied in the many literature and several solutions have been proposed.

These solutions are based on reliable forwarding. So, Reliable reactive routing protocol is designed to enhance existing routing protocol to provide reliable and energy efficient packet delivery. These new protocols apply the on-demand procedures to dynamically build the route between a source and a destination. Routes are generally created and maintained by two different phases, namely: route discovery and route maintenance. Route discovery usually occurs on-demand by flooding an RREQ (Route Request) through the network. When a route is found, the destination returns an RREP (Route Reply), which contains the route information traversed by the RREQ. This new protocol extends AODV's properties and overcome the limitations of traditional routing and proposes new AODV_R3E which increase its effectiveness and feasibility.

Michael Cheffena[1] proposes A complete dynamic wideband channel model for industrial wireless sensor network. In harsh industrial environments the interferences, heavy multipath propagation and noises are present. So this model takes into account the noise, interferences, and heavy multipath propagation in harsh industrial environments. A first order two-state Markov process is adopted to describe the typical busty nature of the impulsive noise usually present in industrial environments this proposed channel model generating time series which can be used for successfully designing robust industrial WSNs and for simulating the performance of WSNs in harsh industrial environments. Performance evaluations of IEEE 802.15.4 in terms of bit error rate using the developed channel model are presented. They also demonstrate the advantage of using link diversity (in addition to spread spectrum techniques) to improve the link quality in harsh industrial environments.

Charles E Perkins and Elizabeth M Royer [3] present Ad-hoc on Demand Distance Vector Routing protocol. For the Ad-hoc network AODV is an efficient algorithm AODV provides loop free routes even while repairing broken links. AODV provides quick response to link breakage in active routes. This new routing algorithm is quite suitable for a dynamic self starting network as required by users wishing to utilize a Ad-hoc networks AODV provides most of the advantages of basic distance vector routing mechanisms .This algorithm scales to large populations of mobile nodes wishing to form ad-hoc networks.

Mahesh K. Marina and Samir R. Das [4] present on demand multipath distance vector protocol for mobile ad-hoc networks in each route discovery it find multiple routes between source and destination i.e Multipath extensions to single path routing protocol For simulating the performance using ns-2 simulations AOMDV with AODV AOMDV is able to achieve remarkable improvement in the end-to-end delay able to reduce routing overheads. Primary design goal behind AOMDV is to provide efficient fault tolerance in the sense of faster and efficient recovery from route in dynamic routing.

David B. Johnson David A. Maltz [5] present Dynamic Source Routing (DSR) protocol for routing in Ad-hoc wireless network. That uses dynamic source routing in dynamic source routing when host movement is frequent the protocol adapts quickly to routing changes. In an ad hoc network, this protocol performs well over a variety of environmental conditions such as host density and movement rates. This paper describes EXOR [9] an integrated routing and MAC protocol that increases the throughput of large unicast transfers in multi-hop wireless networks. EXOR chooses each hop of a packet's route after the transmission for that hop, so that the choice can reflect which intermediate nodes actually received the transmission.

This paper proposes COPE [11] a new architecture for wireless mesh networks. In addition to forwarding packets, routers mix (i.e., code) packets from different sources to increase the information content of each transmission. Author demonstrates that intelligently mixing packets increases network throughput. Again COPE design is rooted in the theory of network coding**.** COPE inserts a coding shim the IP and MAC layers. COPE may be useful for cellular relays.

Deploying cellular base stations is usually expensive A cheap way to increase coverage is to deploy relay nodes that intervene between the mobile device and the base station creating a multi-hop cellular backbone. COPE would allow cellular relays to use the bandwidth more efficiently.

Szymon Chachulski Michael Jennings [12] these two authors present MORE a MAC-independent opportunistic routing. Multiple nodes may hear a packet broadcast and unnecessarily forward the same packet. EXOR deals with this issue by tying the MAC to the routing, imposing a strict scheduler on routers access to the medium protocol. MORE randomly mixes packets before forwarding them. MORE provides both unicast and multicast traffic with significantly higher throughput than both traditional routing and prior work on opportunistic routing .So MORE provide some additional properties for better performance of WSN.

Raffaele Bruno a, Maddalena Nurchis [15] done survey and presented the wireless diversity-based routing paradigm although very promising results have been obtained in terms of throughput and reliability improvements

The strong assumption behind their design is that an application can tolerate a certain delay in exchange for throughput gain. In other words, throughput improvement has been considered the main objective in this research field, while only a little attention has been directed to delay reduction. However, wireless mesh networks are expected to provide advanced communication services supporting real-time traffic. In other words, throughput improvement has been considered the main objective in this research field, while only a little attention has been directed to delay reduction. However, wireless mesh networks are expected to provide advanced communication services supporting real-time traffic.

Kyu-Han Kim and Kang G. Shin [16] proposes a highly efficient and accurate link-quality measurement framework, called EAR (Efficient and Accurate link-quality monitor) in this paper.

First, the above-mentioned three solutions rely heavily on accurate link-quality information to select the best relay nodes. Second, applications, such as video streaming and VoIP, also need the link-quality information to support QoS guarantees over WMNs. Third, diagnosing a network, especially a large-scale WMN, requires accurate long-term statistics of link-quality information to pinpoint the source of network failures, and reduce the management overhead Author proposes a high-accuracy and low-overhead distributed measurement framework, called EAR that has the following three salient features. First, EAR consists of three complementary measurement schemes. Passive, cooperative, and active monitoring. That commonly uses *unicast* for its accuracy. Exploit the egress/cross traffic of each node for efficiency. Using unicast, all three schemes measure link-quality under the same setting as the actual data transmission, thus yielding accurate results

Rodrigo Fonseca, Omprakash Gnawali [17] considers the problem of estimating link quality in an ad-hoc wireless mesh. And they argue that estimating links well requires combining information from the network, link, and physical layers. We propose narrow, protocol-independent interfaces for the layers, which in total provide four bits of information: 1 from the physical layer, 1 from the link layer, and 2 from the network layer .And after various experimental result this prototype has shown significant improvements on cost and delivery ratio over the state of the art, while maintaining layered networking abstractions.

Juan A. Sanchez, Rafael Marin-Perez and Pedro M. Ruiz [18] in this paper, propose BOSS the Beacon-less On Demand Strategy for Geographic Routing in Wireless Sensor Networks. Its design takes into account the losses and collisions of typical radio communications This Beacon-less On Demand Strategy for Geographic Routing in Wireless Sensor Networks Concretely made a practical study to determine the impact of the packet size on the Packet Reception Ratio (PRR).

Eric Rozner and Jayesh Seshadri[23] in this paper proposes a Simple Opportunistic Adaptive Routing protocol (SOAR) to explicitly support multiple simultaneous flows in wireless mesh networks. SOAR incorporates the following four major components to achieve high throughput and fairness: (i) adaptive forwarding path selection to leverage path diversity while minimizing duplicate transmissions, (ii) priority timer-based forwarding to let only the best forwarding node forward the packet, (iii) local loss recovery to efficiently detect and retransmit lost packets, and (iv) adaptive rate control to determine an appropriate sending rate according to the current network conditions. SOAR act as a novel opportunistic routing protocol. SOAR effectively realizes opportunistic forwarding by judiciously selecting forwarding nodes and employing priority-based timers. It further incorporates adaptive rate control to dynamically adjust sending rates according to network conditions and recovers lost packets using efficient local feedback and recovery.

In this paper Jianfeng Wang, Hongqiang Zhai, Wei Liu and Yuguang Fang [22] present a new cross-layer approach based on AQDV and 802.11 MAC to utilize the local path diversity. This paper provides a scheme to utilize the local path diversity in improving the reliability **a**nd efficiency of packet forwarding in the multihop ad- hoc networks. Propose scheme is build over AODV routing and 802.11 MAC. It is critical to provide high-rate, reliable and energy efficient wireless communication in mobile ad hoc networks. The use of path diversity is a promising way to achieve this objective but it requires careful cross-layer design.

Yanjun Li, Chung Shue Chen, Ye-Qiong Song, Zhi Wang, Youxian Sun [27] proposes a two-hop neighborhood information-based geographic routing protocol. Which enhance the service quality of real-time packet delivery for WSN. This protocol is proposed for real-time wireless sensor networks. The approach of mapping packet deadline to a velocity is adopted as that in SPEED; however, the routing decision is made based on the novel two-hop velocity integrated with energy balancing mechanism. Initiative drop control is embedded to enhance energy utilization efficiency, while reducing packet deadline miss ratio. Simulation and comparison show that the new protocol has led to lower packet deadline miss ratio and higher energy efficiency than two existing popular schemes. The result has also indicated a promising direction in supporting real-time quality-of-service for wireless sensor networks. An energy-efficient packet drop control is incorporated to enhance energy utilization efficiency while keeping low packet deadline miss ratio. The actual characteristics of physical and MAC layers are captured in the simulation studies. Simulation results show that, compared with SPEED and the –routing which both only utilize one-hop information, THVR has achieved lower end-to-end deadline miss ratio and higher energy utilization efficiency.

Yanjun Sun Omer Gurewitz[21] present the design and evaluation of ADB (*Asynchronous Duty-cycle Broadcasting*) a new protocol for efficient multihop broadcast in wireless sensor networks using synchronous duty-cycling.ADB efficiently collects and distributes information on broadcast progress, substantially reducing redundant transmissions, collisions, and energy consumption by allowing a node to transmit to only a subset of neighbors and to go to sleep as soon as possible. ADB substantially reduces delivery latency by avoiding collisions and transmissions over poor links. Author proves that ADB achieves close-to-optimal delivery latency with error and collision-free links. ADB shows much higher energy efficiency and significantly reduces network load, while maintaining low delivery latency and over 99% packet delivery ratio.

V.C. Gungor a, F.C. Lambert b [25] Here presents the opportunities and challenges of hybrid network architecture that are discussed for electric system automation applications. More specifically, Internet based Virtual Private Networks, power line communications, satellite communications and wireless communications (wireless sensor networks, WiMAX, wireless mesh networks) are described in detail. The motivation of this paper is to provide a better understanding of the hybrid network architecture that can provide heterogeneous electric system automation application requirements. In this regard, main aim of author is to present a structured framework for electric utilities who plan to utilize new communication technologies for automation and hence, to make the decision making process more effective and direct.

Qing Cao1, Tarek Abdelzaher1, Tian He2, Robin Kravets1 [24] present cluster-based forwarding, where each node forms a cluster such that any node in the next-hop's cluster can take forwarding responsibility. This architecture, designed specifically for wireless sensor networks, achieves better energy efficiency by reducing retransmissions. Cluster-based forwarding is not a routing protocol. Rather, it is designed as extension layers that can augment existing routing protocols. By using simulations result are drawn. And this result demonstrates that cluster-based forwarding is effective in improving both end-to-end energy efficiency and latency of current routing protocols**.** It also reduces end-to-end cost and delay for generic routing protocols. While CBF is designed for low-data-rate sensor networks where congestion is rare, study will done how to extend CBF to congested sensor networks in future work. CBF may need to be modified because when congestion exists, the link quality may change dramatically from time to time, and helpers need to be updated in time to compensate for such changes.

Filip Barac, Kan Yuy, Mikael Gidlundz, Johan A° kerbergz and Mats Bjorkmany[28] address the issues of timeliness and transmission reliability of existing industrial communication standards. Author combine a Forward Error Correction coding scheme on the Medium Access Control layer with a lightweight routing protocol to form an IEEE 802.15.4-conformable solution, which can be implemented into already existing hardware without violating the standard. The lightweight nature of the routing component contributes to latency reduction due to its lack of control messages and routing meanwhile, the reliability is increased because redundant paths are used to deliver packets. Apart from the obvious contribution to reliability, the coding component reduces the latency .Redundant paths provided by the routing component have different delays and the use of FEC coding increases the probability that the packet will be successfully delivered via the path with the minimum delay.

Tapiwa M. Chiwewe and Gerhard P. Hancke [26] research a topology control technique for energy efficient and low interference in wireless sensor networks was developed in the form of the SBYaoGG algorithm. The SBYaoGG algorithm was evaluated using a simulation program and was shown to perform favorably. The first step is to ensure that all links in the graph are symmetric by adding the reverse edge of all asymmetric links. This helps to ensure good energy efficiency by keeping the power spanning ratio down. The second optimization step is to set the transmitter power of each node to the minimum power that is necessary to reach the furthest neighbor with which it has a link in the topology controlled graph.

In this paper, author describe the Optimization of Communication for Ad hoc Reliable Industrial networks (OCARI)[6] project in which they try to developed a wireless sensor communication module running an industrial ad-hoc mesh net working protocol. It is based on IEEE 802.15.4 PHY layer and satisfies the following criteria in harsh environment.

Author propose an advanced Received Signal Strength (RSS)based flooding scheme[7]. Main approach contains two main components. First, each node within the network needs to be assigned with a weight value.

The sink periodically broadcasts a weight-updated message to all other nodes. Each node weights itself via Received Signal Strength Indicator (RSSI) values of incoming messages and the message weight according to this proposed weighting algorithm and forwards the message to other nodes, when a node intends to transmit packets to the sink; the node inserts its own weight into its packets and broadcasts it to its neighbors. All packets from this node are only forwarded by the intermediate nodes with less weight. Since the sink is assigned with the weight zero, all packets will finally arrive at the sink. Based on this proposed routing approach, any path failure or change of the network topology will not trigger a route recalculation and interrupt data transmissions, since this proposed approach is entirely free of routing tables.

Xufei Mao, Shaojie Tang[14] addresses how to select and prioritize the forwarding list to minimize the total energy cost of forwarding data to the sink node in a wireless sensor network (WSN). Several interesting and challenging problems are left unsolved here. An interesting question is to design efficient protocols for selecting optimum forwarder list for multicast and broadcast. A challenge is to compute the expected cost accurately when consider need of the additional overhead by sensor nodes for agreeing a unique node in the forwarder list to forward the data when multiple nodes could have potentially received the data correctly. It is interesting to design protocols using opportunistic routing that deliver the data most reliably, or deliver the data with the minimum delay.

Opportunistic routing [2], [3] has been shown to improve the network throughput, by allowing nodes that overhear the transmission and closer to the destination to participate in forwarding packets, i.e. in forwarder list. The nodes in forwarder list are prioritized and the lower priority forwarder will discard the packet if the packet has been forwarded by a higher priority forwarder. One challenging problem is to select and prioritize forwarder list such that a certain network performance is optimized

.Seong-eun Yoo, Poh Kit Chong, Yoonmee Doh[2] Minh-Long Pham proposed a real-time message scheduling algorithm. Generally this proposed model can be used for generating time series which is used for simulating and successfully designing robust WSNs for industrial applications.This algorithm is distance constrained real-time off-line message scheduling algorithm which generates the standard specific parameters such as BO, SO and GTS information and allocates each periodic real-time message to super frame slots for a given message set. This scheduling algorithm can schedule a given periodic real-time message set, and the algorithm determines the appropriate standard specific parameters such as BO, SO, and GTS descriptor to meet the timing constraints for IEEE 802.15.4 based industrial WSN.

Kai Zeng Wenjing Lou [13] studied and understand the geographic collaborative forwarding (GCF) scheme, a variant of opportunistic routing, which exploits the broadcast nature and spatial diversity of the wireless medium to improve the packet delivery efficiency and the tradeoffs of the node collaboration and its associated cost, thus provide insightful analysis and guidance to the design of more efficient routing/forwarding protocols.

Michele Zorzi, and Ramesh R. Rao[20] in this paper propose a novel forwarding technique based on geographical location of the nodes involved and random selection of the relaying node via contention among receivers. They focus on the multihop performance of such a solution, in terms of average number of hops to reach a destination as a function of the distance and of the average number of available neighbors. The actual node which acts as a relay is not known a priori by the sender but rather is decided after the transmission has taken place. This idea leverages on the fact that in the wireless environment broadcast is free (from the sender's point of view) and that in the presence of randomly changing topologies a node may not be aware of which of its current neighbors is in the best position to act as a relay . An idealized scheme (in which the best relay node is always chosen) is discussed, and its performance is evaluated by means of both simulation and analytical techniques.

Vehbi Cagri Gungor, Özgür B. Akan, Ian F. Akyildiz [9] presents a Real-Time and Reliable Transport (RT) protocol for WSANs. The objective of the (RT) protocol is to reliably and collaboratively transport event features from the sensor field to the actor nodes with minimum energy dissipation and to timely react to sensor information with a right action. In this respect, the (RT) protocol simultaneously addresses congestion control and timely event transport reliability objectives in WSANs. To the best of their studied knowledge, this is the first research effort focusing on real-time and reliable event transport and action performance objectives of WSANs.

Kai Zeng Wenjing Lou [19] further proposed a heuristic algorithm to select the forwarding candidates and prioritize them. The simulation results validated the analysis and showed that GOR achieves higher one-hop throughput as well as path throughput than the corresponding pure opportunistic routing and geographic routing schemes.

Author introduce a framework to analyze the one-hop throughput of GOR, provide a deeper insight into the trade-off between the benefit (packet advancement and transmission reliability) and cost (medium time delay) associated with the node collaboration, and propose a local metric named *expected one-hop throughput* (EOT) to balance the benefit and cost. And also identify an upper bound of EOT and its concavity, which indicates that even if the candidate coordination delay were negligible, the throughput gain would become marginal when the number of forwarding candidates increases. Based on the EOT, also propose a local candidate selection and prioritization algorithm. Simulation results validate the analysis and show that the EOT metric leads to both better one-hop and path throughput than the corresponding pure GOR and geographic routing. In this paper, author studied the GOR scheme and analyzed the trade-off among the packet advancement, reliability and MAC coordination time cost in GOR. After studying GOR scheme author introduced a new local routing metric, the EOT, to balance these factors. And then derived an upper bound of the EOT and revealed its concavity, which indicates that although involving more forwarding candidates brings more chances for the packet to get closer to the destination and be delivered, the gained benefit becomes marginal when they keep doing so. The EOT upper bound analysis also manifests that if the coordination delay among the forwarding candidates were negligible, the maximum EOT could be achieved by giving candidates closer to the destination higher relay priorities.

4. CONCLUSION

In this paper, we have reviewed different existing models and techniques for reliable forwarding in WSN. By analyzing the existing system we will propose biased back off scheme during the route discovery phase to find a robust guide virtual path, which can provide more cooperative forwarding opportunities as well as a new R3E protocol this protocol is the extended AODV- R3E protocol which can effectively improve robustness, reliable and energy efficient packet delivery against unreliable wireless links and Provide solution to reliable route discovery and efficient cooperative forwarding problems. Simulation results showed that, as compared with other protocols, AODV-R3E can effectively improve robustness, end-to-end energy efficiency, latency and reliability.

REFERENCES

[1] V. Gungor and G. Hancke, "Industrial wireless sensor networks: Challenges, design principles, and technical approaches," IEEE Trans. Ind. Electron., vol. 56, no. 10, pp. 4258–4265, Oct. 2009.

[2] S. eun Yoo, P. K. Chong, D. Kim, Y. Doh, M.-L. Pham, E. Choi, and J. Huh, "Guaranteeing real-time services for industrial wireless sensor networks with IEEE 802.15.4," IEEE Trans. Ind. Electron., vol. 57, no. 11, pp. 3868–3876, Nov. 2010.

[3] C. Perkins and E. Royer, "Ad-hoc on-demand distance vector routing," in Proc. IEEE WMCSA, 1999, pp. 90–100.

[4] M. Marina and S. Das, "On-demand multipath distance vector routing in ad hoc networks," in Proc. IEEE ICNP, Nov. 2001, pp. 14–23.

[5] D. B. Johnson and D. A. Maltz, "Dynamic source routing in ad hoc wireless networks," Mobile Computing, pp. 153–181, 1996.

[6] K. A. Agha, M.-H. Bertin, T. Dang, A. Guitton, P. Minet, T. Val, and J.-B. Viollet, "Which wireless technology for industrial wireless sensor networks? the development of Ocari technology," IEEE Trans. Ind. Electron., vol. 56, no. 10, pp. 4266–4278, Oct. 2009.

[7] K. Yu, M. Gidlund, J. Åkerberg, and M. Björkman, "Reliable RSS-based routing protocol for industrial wireless sensor networks," in Proc. IECON, 2012, pp. 3231–3237.

[8] "U. D. of Energy, Industrial wireless technology for the 21st century," Office of Energy and Renewable Energy Report, 2002.

[9] V. Gungor, O. Akan, and I. Akyildiz, "A real-time and reliable transport protocol for wireless sensor and actor networks," IEEE/ACM Trans. Netw., vol. 16, no. 2, pp. 359–370, Apr. 2008.

[10] S. Biswas and R. Morris, "ExOr: opportunistic multi-hop routing for wireless networks," in Proc. ACM SIGCOMM, 2005, pp. 133–144.

[11] S. Katti, H. Rahul, W. Hu, D. Katabi, M. Medard, and J. Crowcroft, "XORs in the air: Practical wireless network coding," IEEE/ACM Trans. Netw., vol. 16, no. 3, pp. 497–510, Jun. 2008.

[12] S. Chachulski,M. Jennings, S. Katti, and D. Katabi, "Trading structure for randomness in wireless opportunistic routing," in Proc. AGM SIGCOMM, 2007, pp. 169–180.

[13] K. Zeng, W. Lou, J.Yang, and D. Brown, "On geographic collaborative forwarding in wireless ad hoc and sensor networks," in Proc. WASA, 2007, pp. 11–18.

[14] X. Mao, S. Tang, X. Xu, Li X.-Y, and H. Ma, "Energy-efficient opportunistic routing in wireless sensor networks," IEEE Trans. Parallel Distrib.Syst., vol. 22, no. 11, pp. 1934–1942, Nov. 2011.

[15] R. Bruno and M. Nurchis, "Survey on diversity-based routing in wireless mesh networks: Challenges and solutions," Computer Commun., vol. 33, no. 3, pp. 269–282, Feb. 2010.

[16] K.-H. Kim and K. G. Shin, "On accurate measurement of link quality in multi-hop wireless mesh networks," in Proc. ACM MobiCom, 2006, pp. 38–49.

[17] R. Fonseca, O. Gnawali, K. Jamieson, and P. Levis, "Four-bit wireless link estimation," in Proc. HotNets VI, 2007, pp. 1–7.

[18] J. Sanchez, R. Marin-Perez, and P. Ruiz, "Boss: Beacon-less on demand strategy for geographic routing in wireless sensor networks," in Proc. IEEE MASS, 2007, pp. 1–10.

[19] K. Zeng,W. Lou, J. Yang, and D. R. Brown, "On throughput efficiency of geographic opportunistic routing in multihop wireless networks," Mobile Netw. Applicat., vol. 12, no. 5, pp. 347–357, 2007.

[20] M. Zorzi and R. R. Rao, "Geographic random forwarding (GeRaF) for ad hoc and sensor networks: Energy and latency performance," IEEE Trans. Mobile Comput., vol. 2, no. 4, pp. 349–365, Apr. 2003.

[21] Y. Sun, O. Gurewitz, S. Du, L. Tang, and D. B. Johnson, "ADB: an efficient multihop broadcast protocol based on asynchronous dutycycling in wireless sensor networks," in Proc. ACM SenSys, 2009, pp. 43–56.

[22] W. A. Hoc, J. Wang, H. Zhai, W. Liu, and Y. Fang, "Reliable and efficient packet forwarding by utilizing path diversity in wireless ad hoc networks," in Proc. IEEE Milcom, 2004, pp. 258–264.

[23] E. Rozner, J. Seshadri, Y. Mehta, and L. Qiu, "Soar: Simple opportunistic adaptive routing protocol for wireless mesh networks," IEEE Trans. Mobile Comput., vol. 8, no. 12, pp. 1622–1635, Dec. 2009.

[24] Q. Cao, T. Abdelzaher, T. He, and R. Kravets, "Cluster-based forwarding for reliable end-to-end delivery in wireless sensor networks," in Proc. IEEE INFOCOM, 2007, pp. 1928–1936.

[25] V. C. Gungor and F. C. Lambert, "A survey on communication networks for electric system automation," Comput. Netw., vol. 50, no. 7, pp. 877–897, May 2006.

[26] T. Chiwewe and G. Hancke, "A distributed topology control technique for low interference and energy efficiency inwireless sensor networks," IEEE Trans. Ind. Inf., vol. 8, no. 1, pp. 11–19, Feb. 2012.

[27] Y. Li, C. S. Chen, Y.-Q. Song, Z.Wang, and Y. Sun, "Enhancing realtime delivery in wireless sensor networks with two-hop information," IEEE Trans. Ind. Inf., vol. 5, no. 2, pp. 113–122, May 2009.

[28] F. Barac, K. Yu,M. Gidlund, J. Akerberg, andM. Bjorkman, "Towards reliable and lightweight communication in industrial wireless sensor networks," in Proc. IEEE INDIN , 2012, pp. 1218–1224.