A Comprehensive Survey on Cooperative Relaying in Industrial Wireless Sensor Network

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***Abstract*— An increasing growth and dynamic nature of industrial environment along with an improvement over productivity and efficiency of the system has led to usage of sensor network. In industrial scenario, degradation of received signal strength owing to various obstacles along with modes of propagation. Due to harsh environment, the signal are affected with noise, fading and interference that disturbs the transmission. Eventually, the fading effect and interference can be suppressed with the help of virtual MIMO and spatial diversity which constitutes a technique known as Cooperative Relaying. This technique improves the reliability and signal quality through an effective selection of relay. The relay selection plays an important building block to realize cooperative relay in industrial scenarios. The temporal and spatial nature of the interference has a major role in shaping the system performance in harsh environment. This paper presents various relaying techniques and parameter involved in selecting an optimal relay for industrial environment.**

Keywords*— *Cooperative diversity; Cooperative Relaying; Diversity Combining; Interference; Industrial Wireless sensor network; Relay selection, SINR/BER

I. INTRODUCTION

An increasing interest in adoption of real time wireless network for industrial communication has gained opportunity for improving the capacity and capability of the system. Conventionally, industrial automation systems are achieved only with the help of wired link which requires expensive cable to be equipped and systematically maintained. Some of the monitoring process can be accomplished by humans such as out of reach state, high vibration RF interference, high humidity levels, dust and dirt. The recent upgradation in the domain of wireless sensor networks (WSN) has made a recognition for low-cost embedded industrial automation system to be achievable. Therefore, Wireless sensor networks (WSN) have attained interest for industrialization since replacement of fading wired industrial communication networks. The Wireless automation system provides relatively low system and infrastructure costs, convenience of installation, easy upgrading and relocating with physical mobility. The *Industrial Wireless Sensor Network* (IWSN) has an inherent to enhance capability of industrial systems by contributing pre-awareness, control and integration of business modules. The wireless tiny sensor nodes are introduced to industrial equipment that are used for monitoring and control of production processes of extremely dynamic environment. The IWSN is depicted with nodes, sink/network manager, management console, and process controllers. The node collects data and transmits to the sink/network manager which communicates with the process controller. Every node in the industrial environment are managed by the network manager [1].Often sensor nodes placed inside the factory, faces the impact of propagation environment due to interference and radio waves produced by machines. Thus the sensor nodes deployed in industrial environment are subjected to harsh environment such as dynamic in quality of wireless links, Radio Frequency interference, multipath fading and severe signal shadowing due to industrial machine and also living beings. Reliability and latency are required in WSNs to guarantee real-time communication for industrial automation. IWSN are deterministic system where there is no randomness in generating future state of system, there is a predictable network latency and fault tolerance of the network.

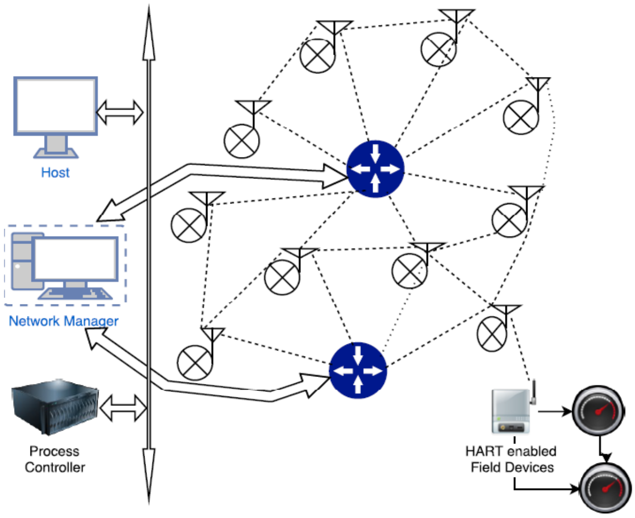

Fig.1 IWSN Architecture

Recently, many communication standards such as WirelessHART, ISA100.11a and Zigbee for process monitoring and control along with 802.15.4 for low power devices in industrial environment. Tiny sensors is connected on industrial machines, which monitors the parameter critical based on the measurement like vibration, increase in temperature, pressure and power control. Henceforth, the transmitted data from sensor nodes are analyzed by the sink meanwhile any potential problem been identified in the industry plant are notified as advanced warning system. This enables plant or harsh environment to adjust or replace the machines before their performance quality either decreases or drops suddenly. Thus catastrophic equipment failure and associated repair can be prevented in advance with the help of sensor node in industrial environment. Due to the harsh environmental condition, packet transmitted may be corrupted by channel conditions which results in degradation of received signal. It requires retransmission for increasing end-to-end packet delay and reduced network throughput. Hence, the technique having two or more antennas which is coined to be spatial diversity is used to improve the quality and reliability of wireless link. It mitigates the negative effects of fading and interference over the communication channel. The spatial diversity in the wireless environment could be exploited by coding across the cooperating users. To improve the communication, Multiple Input Multiple Output (MIMO) technique is used which is a conventional form of antenna/spatial diversity with a physical antenna at both ends. The cooperative communications has the ability to mitigate the effect of fading in wireless networks via antenna diversity, however it resolves the difficulties of installing multiple antennas on small communication terminals [2].

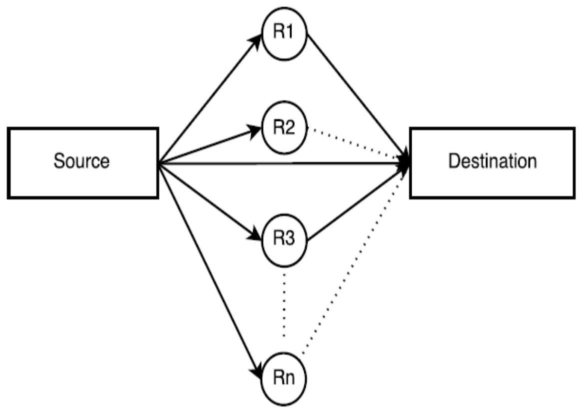

Fig. 2 Cooperative Relaying

In cooperative communication, multiple user mutually share and coordinate their resources to improve the quality of data transmission where multiple source node can act as relays for each other [12]. Thus the number of relay nodes assigned are used to help the source in forwarding its data to the desired destination, hence forming a virtual antenna array. It improves the reliability and data rate in wireless link. But the usage of multiple co-located antenna degrades the Quality of service. Thus virtual MIMO was introduced, single antenna reap the function of multiple antenna which is coined as Cooperative diversity. Cooperation can resist the shadowing effect by relaying the transmitted signal. The concept of cooperative diversity is to eliminate the effects of small scale fading and exploits alternative communication paths from other nodes in the vicinity of sender and receiver of a currently affected communication link. The effect of fading and shadowing are suppressed with help of Cooperative Diversity [3], hence this technique is widely used in IWSN for reliable communication. The other nodes act as relay node, which assists in forwarding information from a source to destination nodes. These relay terminals can cooperate with the source to transmit the data to the destination. The relay nodes utilizes the broadcast nature of the wireless medium to overhear the transmitted packet between the source and destination. With the help of relay nodes, the quality of signal received at the destination. The relay nodes forward the data to the destination which decodes the combination of relay data along with original data via cooperative diversity. The placement of the relay nodes entirely depends on the associated channel. The relay nodes has achievable rates through different random coding schemes such as facilitations, cooperation, observations. These relay are not pre-determined but have to be chosen from set of available terminals. The goal of relay nodes is to optimize the transmission time for the given data. The transmission times consist of time required for both sink-relay link and relay-destination link [4]. The Cooperative Communication aims to process and forward the overhead information to its destination to create spatial diversity, which results in increasing system performance. In the cooperative mode the node which overhears a data, can forward it to its next-hop node. This node is termed as cooperative node. The next-hop node of the data may receive redundant data from the original source node along with several cooperative nodes, it combines and decodes them. The source decides which relay terminals to cooperate based on an appropriate relay selection. If direct transmission fails, received packet in relay node is retransmitted to the destination [5]. The transmission time depends on the source-to relay link and the relay-to-destination link.

The remainder of this paper is structured as follows: In section II we present the Relaying techniques, and section III present the modes of Relaying schemes. In section IV describes the Parameter involved in Relay selection.

II. RELAYING STRATEGIES

The relay nodes provides three main benefits like Throughput enhancement, Coverage extension, reduces cost. The proper placement of relay nodes will enable spatial reuse which leads to increased throughput and also enhances coverage reliability over the shadowed region of the base station. It also reduces the need for additional antenna since relay node can extend the relaying facility in a reduced cost manner [11]. These relaying nodes are mainly categorized into two scheme as depicted in the figure [3]. The fixed scheme are simple method in which every transmitted signal is analyzed for its noisy content either by amplifying, demodulating or through detecting with help of relay nodes and its encoded version is received in the receiver side. However, the selective scheme primarily detects for any error with help of some mechanism and then forward to its destination.

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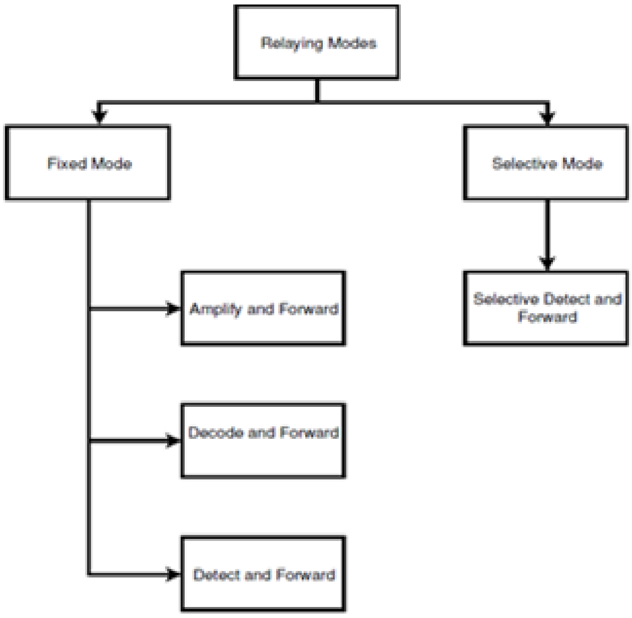

Fig.3 Relaying Strategies

A. Amplify and Forward:

In Amplify and Forward [2], the relay node receives a noisy version of the signal transmitted by its source node which is amplified and retransmitted to the next node. The destination will combine the data from its source and relay nodes. It is a simple method which requires much less computing power as no decoding or quantizing operation is performed at the relay side. Although the noise is amplified, the destination receives two independently-faded versions of the signal and are able to make better decisions for the transmitted symbols. The amplification factor exhibits an inverse relation to the power received.

B. Decode and Forward:

In Decode and Forward [2], the received signal from the source is first decoded and then re-encoded. Hence it does not exhibit any amplified noise in the transmitted signal as of like Amplify and Forward method. The relay can completely decode the original message from the source node and checks for any error in the original data with the help of error correcting code and finally encodes the data. At the last Encoded signal is send to destination. This technique requires a lot of computing time and the information sent by the relay does not include any additional information regarding the reliability of the source-relay link. This technique is termed as re-generative relaying protocol. Due to the nature of regenerative relaying, it can eliminate the signal to noise ratio from the inter-user signal. They neither perform any error correction or checksum over the received signal.

C. Detect and Forward:

In Detect and Forward (DtF) [11], the signal is demodulated/detected by the relay and then sent to the destination. The encoded signal from source is not fully decoded by the relay. Hence this technique is less complicated as compared to Detect and Forward scheme. DtF is also termed as re-generative scheme as the signal is detected and regenerated before it gets transmitted. However, DtF and DF belongs to the equivalent divisions of relaying schemes. DtF is also termed as fixed DF which gives coding gain instead of diversity gain and it also acts as a repetition code. DF decodes the received signal entirely while DtF retransmits the symbols without fully decoding them.

D. Selective Detect and Forward:

This scheme is assorted into Selective scheme of relaying. The relay node identifies the source transmission, if it is error free then it is forwarded to the destination. Some error detection mechanism are implemented in the relay node to identify the error in data sent by the source. This kind of scheme eliminates the problem of error propagation.

III. DIVERSITY COMBINING TECHNIQUES

Diversity combining is the approach used to unite together various signals received by diversity reception device into a resulting output and improves the signal. The combining strategies can be categorized into five ways [8]:

- Equal Ratio Combining (ERC),
- Fixed Ratio Combining (FRC),
- Selection Combining (SC),
- Threshold Combining (TC), and
- Maximum Ratio Combining (MRC).

ERC is the simplest method where equal weights are assigned to all individual incoming data. The obtained signals are combined equally when it is difficult to estimate the channel quality. In FRC, the incoming signals are measured with a constant ratio instead of combining them. This infers the average channel quality and does not consider influences on the channel that happened by fading or other effect. In SC, each independent path that has the higher signal to noise ratio is selected at the receiver side. TC is a variation of SC where the signal with signal to noise ratio value above the predefined threshold level are identified. In MRC, the best possible performance of the signal is attained by multiplying each and every input signal with its respective conjugated channel gain. Taking into consideration that the receiver has full knowledge of channels phase shift and attenuation & optimizes the output SNR.

IV. COOPERATIVE RELAYING METHODS

The Relaying technique is classified into two ways as depicted in the figure [2]. In conventional transmission, the source will transmit the data only to its next-hop node which accepts it while all other nodes ignore the data, these data are finally transmitted to destination by the desired next hop nodes. The cooperative transmission uses the broadcasting nature of wireless transmitter to improve the performance. The node overhears the data and forward it to the next hop node after performing some processing depends on cooperative transmission scheme. The next hop node of data may receive multiple data from transmitted node. The cooperating node combines and decodes the data. Thus the performance of transmission is improved when compared with direct transmission. In cooperative diversity protocols, the transmission of packets is based on two phases [3]:

- Phase 1: Coordination phase – In this phase, users (source, destination, relay) exchange their own source data and control messages with each other or the destination.
- Phase 11: Cooperation phase - In this phase, the users cooperatively retransmit their messages to the destination.

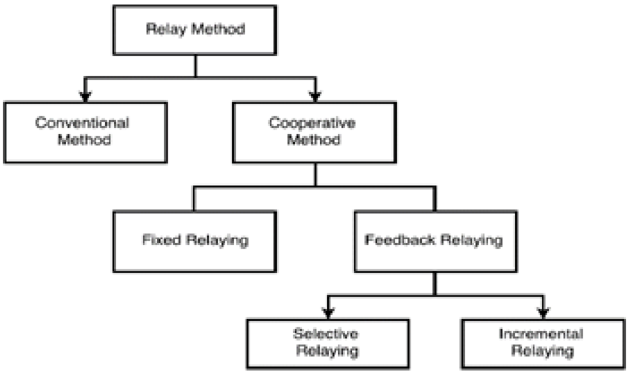

Fig. 4 Cooperative Relaying Method

A. Fixed Relaying:

In Fixed Relaying [13], the channel communication between the source and relay node is in deterministic manner. It can transmit the data in two methodology namely Fixed Amplify and forward and Fixed Decode and Forward. In fixed AF, the relay scales the received version and transmits its amplified version to the destination [4]. The relay receives the noisy version of signal from its sender. The relay node then amplifies and retransmit the noisy signal. The destination will combine the user as well as relay information and make a final decision on the received signal. In fixed DF, the relay nodes just decode the received signal and re-codes it to the destination. They neither perform any error correction or checksum over the received signal. If any incorrect signal is transmitted to destination, then decoding is meaningless at the destination. The diversity achieved in this scheme is unity, since the system performance is limited by damaged link in the communication channels.

B. Feedback Relaying:

1) Selection Relaying:

Selection relaying [4][13] is performed by considering fading coefficient as the key factor. The transmitting terminals can choose a satisfactory cooperative action based on the measured signal to noise ratio between the terminals. Fading coefficients can be measured accurately in cooperative terminals and they can be known to the receivers. The transmission is adapted only based on the fading coefficients. The adaptation is done based on two categorizes namely:

- Measured fading coefficient falls below a certain threshold: The source transmits data directly to the destination, in the form of repetition or more powerful codes.
- Measured fading coefficient lies above the Threshold: The relay transmits the data by either by AF or DF to achieve diversity gain.

In this methodology, the selection of best relay is based on the knowledge of order statistics. Initially, the weaker link is identified between the consecutive hop of each relay node. These link are then ordered and the one with highest SNR is selected as the candidate relay to its destination.

2) Incremental Relaying:

Incremental relaying [4] increases the performance of fixed or selection relaying by exploiting the limited feedback of destination and relaying mechanism. The fixed and selection relaying can be inefficacious over the channel's level of freedom especially for high rates due to the redundant nature of relays. Incremental relaying protocol exploits less feedback from the destination terminal which enhances spectral efficiency over fixed and selection relaying. This scheme can be visualized as an updated version of incremental redundancy and can be imparted as hybrid automatic-repeat-request (ARQ) in relaying context. In ARQ, the source again sends the data when it gets negative acknowledgment from destination as a feedback. As similar with incremental relaying, the relay retransmits when the direct transmission fails and it exploit the spatial diversity. The feedback information regarding the success or failure is determined by the destination depends on either Signal to noise ratio (SNR) or decoding error. Incremental relaying is used to achieve spectral efficiency and efficient use of degrees of freedom. The retransmission occurs only if the transmitted data fails in first phase. This relaying can be combined with either IAF depends on the relay action.

V. PARAMETER FOR COOPERATIVE RELAY SELECTION

The relay selection is purely stationed on the environment in which nodes are deployed. Cooperative Relaying protocol determines set of relay candidates, from which the actual relay is selected. The effective relay is elected based on level of accuracy over received data from the source. The node with the highest signal to noise ratio is chosen as the relay to transmit the packet to the destination. To evaluate the performance of cooperative relaying in Wireless Sensor Network. The effective selection of relay improves communication reliability between communicating entities. The relay intermission should have the stability between the Source-Relay and Relay-Destination links. The path loss model is derived and it demonstrates the relay update information as the strongest impact for outage probability. The Relay selection metrics are based on

- Relay Update Scheme [7]
- Channel State Information [2]

The relay selection can be analyzed through limited channel state information (CSI) between the source/destination and the relays. However, the selection of relay may also lead to overhead, thus relay update interval are chosen based on changing environment [7]. The relay selection for the industrial environment varies drastically based on the fading, noise and the interference due to machine. In industrial aspects, the relay selection is based on some performance metrics like Channel State Information (CSI), Signal to Noise Ratio (SNR) and Bit Error Rate (BER) [2][10]. In industrial scenario, the relay selection is based on maximum SNR value since it attains a diversity order which is proportional to the availability of relay nodes. The selected relay remains active still the SNR value is greater than the predefined threshold. The selected relay decodes the data successfully and sends a sequence of training bits to its destination which evaluate the channel information. However based on CSI value, the destination will decide which relay nodes should contest in the selection somehow the channel capacity between source and destination is relatively weak due to fading and interference.

VI. CONCLUSION

This paper provides an analysis of relay selection schemes for industrial wireless sensor networks, since a poor selection of relay nodes can degrade the network performance. The distribution of IWSN in the real world is purely based on the capability to evaluate and predict the node's performance aspects like latency, reliable communication link and energy efficiency. However the diverse nature of industrial application-centric and network-centric, has several technical problems still unsolved. Based on a detailed systematic analysis of relay selection has defined a conclusion of three-fold: i) to achieve a stability between the performance of transmission rate over an individual relay node and entire network ii) Selection of relay nodes must be based on certain parameters like signal to-noise ratio in presence of noise, signal to interference to noise ratio in presence of interference and noise or packet error rate or bit error rate the usual channel state should be avoided; iii) mobility of sensor nodes and multi-hop nature are to be sustained with the help of effective relay selection strategies. Cooperative relaying enhances the diversity gain and also reduces outage probability with an improved BER/PER performance. The effective way of selecting the relay nodes can improve the entire network performance in terms of maximum data rate/through put along with reduced power consumption in industrial environment.

VII. REFERENCES

[1] Vehbi C. Gungor and Gerhard P. Hancke "Industrial Wireless Sensor Networks: Challenges, Design Principles, and Technical Approaches" IEEE Transactions On Industrial Electronics, vol. 56, no. 10, October 2009.

[2] Vishal K. Shah, Anuradha P. Gharge "A Review on Relay Selection Techniques in Cooperative Communication", International Journal of Engineering and Innovative Technology (IJEIT) vol 2, Issue 5, November 2012.

[3] Gurpreet Kaur and Partha Pratim Bhattacharya"A Survey on Cooperative Diversity and its Application In Various Wireless Network"International Journal of Computer Science & Engineering Survey (IJCSES) Vol.2, No.4, November 2011.

[4] Rinu Titus, Unnikrishnan M, Premkumar C" A Survey on Incremental Relaying Protocols In Cooperative Communication"International Journal of Research in Engineering and Technology Volume: 03 Special Issue: 15 ,Dec-2014 IWCPS-2014.

[5] Ritesh Madan, Neelesh B. Mehta, Andreas F. Molisch and Jin Zhang "Energy-Efficient Cooperative Relaying over Fading Channels with Simple Relay Selection" IEEE Transactions on Wireless Communications, vol. 7, no. 8, August 2008.

[6] Ahmed S. Ibrahim, Ahmed K. Sadek, Weifeng Su and K. J. Ray Liu "Cooperative Communications with Relay-Selection: When to Cooperate and Whom to Cooperate With?" IEEE Transactions On Wireless Communications, vol. 7, no. 7, July 2008.

[7] Torsten Andre1, G¨unther Brandner1, Nikolaj Marchenko and Christian Bettstetter "Measurement-Based Analysis of Cooperative Relaying in an Industrial Wireless Sensor Network " IEEE 2012.

[8] Abdullah M. Al-Yami, Kamal Harby and Samir Abduljauwad "Industrial Wireless Sensor Networks in the Perspective of Diversity and Spectral Efficiency" IEEE Malaysia International Conference on Communications , November 2013.

[9] Diomidis S. Michalopoulos, Athanasios S. Lioumpas, George K. Karagiannidis and Robert Schober "Selective Cooperative Relaying over Time-Varying Channels" IEEE Transactions On Communications, vol. 58, no. 8, August 2010.

[10] Babak Azimi-Sadjadi Daniel Sexton Ping Liu Michael Mahony "Interference Effect on IEEE 802.15.4 Performance" INSS 2006.

[11] Yogesh Bhute, A. R. Raut "A Survey on Relay Selection Strategies in Cooperative Wireless Network for Capacity Enhancement", International Journal of Computer Applications (0975 – 8887), vol 65– No.25, March 2013.

[12] A. F. M. Shahen Shah, Md. Shariful Islam "A Survey on Cooperative Communication in Wireless Network" I.J. Intelligent Systems and Applications, vol 07, 66-78 , 2014.

[13] Golnaz Farhadi and Norman C. Beaulieu "Fixed Relaying Versus Selective Relaying in Multi-Hop Diversity Transmission Systems" IEEE transactions on communications, Vol. 58, no. 3, March 2010.