



Improved Packet Delivery for Wireless Sensor Networks Using Local Automate Based Autonomic Network Architecture in a ZigBee Environment

K. N. Sanjay^{1,2(✉)}, K. Shaila², and K. R. Venugopal³

¹ Department of Electronics and Communication Engineering, VTU-RC, Vivekananda Institute of Technology, Bengaluru, Karnataka, India

sanjaykenkare@gmail.com

² Vivekananda Institute of Technology, Bengaluru, Karnataka, India

³ Bangalore University, Bengaluru, Karnataka, India

Abstract. A low cost, low power personal area network is formalized by IEEE 802.15.4 standard ZigBee Wireless Sensor Network. The most common way to construct a WSN using ZigBee is to use tree type network topology. This leads to large amount of energy consumption because of congestion in network. The node failures in a network topology, results in reconstructing the route of existing structure. Thus, a Local automate based autonomic network architecture is deployed at the MAC layer of ZigBee protocol. The architecture considers previous occurrences of probabilities of nodes and learns their behavior during transmission. This record an active state of each node, that inturn reduces congestion when neighboring node failure occurs. Simulation results provide 20% increase in unicast and multicast delivery rate. Finally, throughput of an entire network in a larger density dynamic environment increases.

Keywords: Autonomic network architecture (ANA) · LACAS · Local automate (LA) · Wireless Sensor Network · ZigBee

1 Introduction

With the expanding modernity of remote correspondences and detecting advances, different sensor-based applications, like industrial robots and electro-mechanical mechanization, creates enormous monetary and social implications. The potential for much more prominent effect has broad investigations on WSNs with ZigBee standards. This determines the industrial system and application layers for detecting information delivery rate [1–3].

The process requires backbone network with static environment and related nodes that are mobile. These nodes rely on the available power supply. Normally, traffic information is overheard to the cluster of a tree and its responsibilities in considering larger

density nodes. The information retrieved by each and every node in network leads to a main cluster node, which simultaneously receives supervisory message leading to congestion in a tree structure [4–6].

The Autonomic network Architecture is as shown in Fig. 1. It comprises of four dependent parameters while designing a MAC layer with ANA architecture.

Sensor Network Application: Disturbances occurred while changing MAC structure with WSNs that should not affect the built-in applications of WSNs.

Self-Configuring, Self-Healing: While introducing ANA, there exists adaptive nature when intermediate nodes fails and re-routes through the shortest path with existing neighboring nodes.

Self-Optimization, Self-Productive: Self-configuration leads to optimization of distance and the network becomes more productive.

Stochastic P2P Overlay: The occurrence of node at each successful transmission leads to consideration of probability in larger density nodes. This, provides basis for stochastic point to point overlay [7–10].

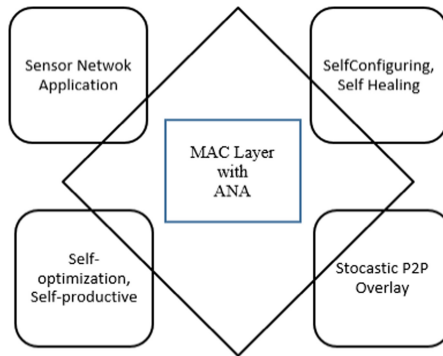


Fig. 1. Autonomic network architecture in MAC layer of WSNs.

Motivation: The vast application of ZigBee in real-time dynamic environment scenario requires design complexity for congestion with unicast and multicast deliveries. These involve designing of active and sleep modes of specific nodes at top layer of a network layer. Thus, designing MAC protocols is a primary concern that involves reliability, fault tolerance and throughput of network in a dynamic environment supporting unicast and multicast deliveries.

Reliability is appreciable during lesser congestion. Fault tolerance can be achieved by providing multi-rate transmission with effective unicast and multicast deliveries. Due to congestion if delivery of packets is unfair, it results in lower throughput. Thus, while designing ZigBee based application the designer has to address end user concern at lower data rates.

Contribution: The integration of complex dynamic environment designed for ZigBee can be achieved using Learning Automate based Autonomic Network Architecture (LA-ANA). The packet delivery ratio is to be optimized in a dynamic environment at smaller space with larger density sensor nodes that involves unicast and multicast delivery rates during low data rate operations. The designed architecture is figured at lower part of network layer of TCP/IP protocol called MAC layer. This provides a feasible solution in handling large sensor nodes by managing its rate of transmission with variable delivery rates. The Master/Slave combination is used with respective nodes based on their probability of occurrence in a routed path within dynamic environment and its range of communication.

Organization: Related work and Problem definition is discussed in Sect. 2 and 3 respectively. System and Mathematical model is discussed in Sect. 4. Implementation of the work using ZigBee with LA-ANA architecture is described in Sect. 5. Simulation and its performance evaluation are discussed in Sect. 6.

2 Related Work

Due to advances in technology for communication in various static and dynamic environments requires multi-rate selection in particular with industrial applications as discussed in [1]. Thus, while operating with lower data rate requires more attention of user and its capability in providing the solution for a desired application. Li et al. [2] utilizes the entire network covering larger density nodes in a dynamic environment that could handle with coexistence networks beyond an available Wi-Fi gains frequency for multiple propagation.

Denial of service attack in autonomicity [3] has to be handled in a better way combining Hilbert transformation along with trust evaluation of sensor node activity. Thus, at transmitting and receiving sections a low cost digital solution can be calculated in handling the congestion along with multicast and unicast packet deliveries. This application can be utilized in real-time health monitoring systems and in railway monitoring that are self-powered and has higher throughput as discussed in [4–7].

In designing, application oriented protocol disturbing MAC layer of the network using autonomicity is considered. It includes interference aware with layer decomposition [8]. This involves threading channels and their dependencies on neighboring network cast. Thus, leading to multi-packet reception and can be efficiently used in an indoor dynamic environments [9, 10].

The module based approach as discussed in [11] provides a feature selection that discriminates multiple analysis for device omission and fewer electrical applications. This brings in an enhancement in IoT and the concept of coexistence [12]. The module leads to two layered design in a ZigBee environment, increasing implementation cost but provides low powered network. This requires fast error recovery techniques as robustness in WSNs is different [13, 14].

3 Problem Definition

Problem Statement: The dynamic environment design using ZigBee with transmission of large number of packets at comparable low data rate can cause congestion. This can be avoided by limiting unicast and multicast delivery.

The objective of our work is to.

- i. Implement unicast and multicast at lower rate of transmission.
- ii. Increasing throughput by considering the active and sleep nodes accordingly in unicast and multicast delivery rate.

Assumptions: Few of our assumption in building the network model are -

- i. Combined process of Local automate and Autonomic Network Architecture.
- ii. Active and Sleep node selection based on their probability of occurrence in a selected shortest path.

4 System and Mathematical Model

The trouble-free network at larger density with low data rate is implemented using LA based ANA architecture. This leads to increased packet delivery ratio and fault tolerance level in a dynamic environment. The architecture involves back pressure mechanism while calculating probability of occurrence of each node and at an initial stage local automate process addresses at lower layer of Network Layer (MAC Layer). This is followed by Autonomic Network Architecture that involves an intermediate node and sink node with data flow rate regulation. This improves the overall packet delivery rate and supports unicast and multicast deliveries during low data rates. Thus, network throughput is substantially increased with lowered fault occurrence.

4.1 Mathematical Model

Let us consider n number of nodes in a ZigBee dynamic environment with specific time t at $n + 1$ scenario is given by,

$$P_{(n+1)} = [P_{(1)}, P_{(2)}, \dots, P_{(i)}, \dots, P_{(n+1)}] \quad (1)$$

where, $P_{(n+1)}$ is the probability of occurrence of each node.

The prediction of an error node and its neighboring data acquired is $e(n + 1)$ and is computed as,

$$e(n + 1) = |P_{(n)}(i + 1) - P_{(n)}(j + 1)| \quad (2)$$

The probability of the i^{th} and j^{th} node with active/sleep mode is considered.

This process, finds actual probability of occurrence of each node in an active path chosen between source and destination.

The ANA based environment can be modeled as $P_{ANA(n)}$ and is given by,

$$P_{(n)} = [P_{(i)}, P_{(j)}, P_{(n+1)}] \tag{3}$$

The selected probability rely on neighboring nodes if an active node fails ($P_{(n)}$). Thus, involving a complete LA-ANA based architecture while routing larger packets in a larger density dynamic environment.

5 Implementation

The LA-ANA based architecture is implemented in two phases for a ZigBee environment. Figure 2 illustrates the random placement of nodes in a dynamic environment. At few places, nodes are nearby and a large gap can be found at center. This kind of randomness is considered and the propagation of unicast and multicast is explained using Fig. 3.

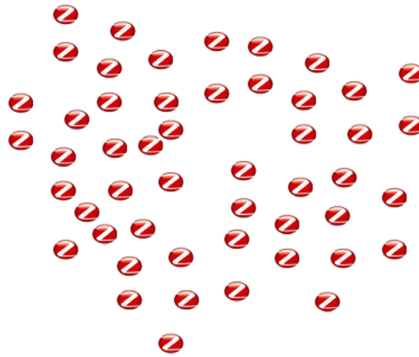


Fig. 2. Sensor nodes are varied from 20–50.

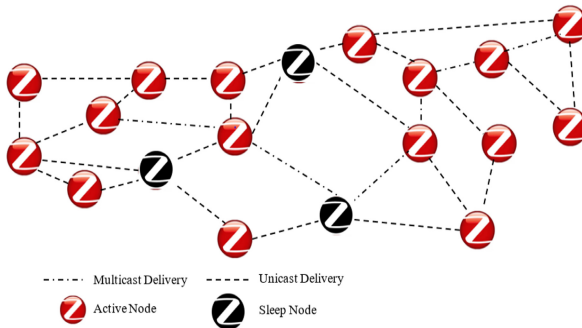


Fig. 3. ZigBee network environment

Multicast delivery is provided for a larger distance and unicast is handled at shorter distance as shown in Fig. 3. The inactive nodes represented, is due to lower battery levels, multiple requests from neighboring nodes and many more such conditions. In such a situation, unicast and multicast delivery rate is switched between nodes based on probability of occurrence in the shortest path. The process is so called *Local automate with Autonomic Network Architecture*. This architecture provides greater adaptability and increased throughput. The process is explained using flowchart as shown in Fig. 4.

In first phase, the network is configured in an AODV environment. Now, source and destinations nodes are located with initial probabilities. The probability of each node is considered based on the occurrence as an intermediate nodes from source to destination.

With shortest path chosen from a source to destination and distance number is provided for the entire selected path. Once, selection is chosen, packets are sent at normal data rate in unicast delivery. The second phase commences as LA-ANA chooses generic path defined primarily in an initial phase.

Now, the algorithm chooses earlier probabilities of nodes and then estimates new distance in case of node failure. Then, second phase returns the determined new probabilities of path that are updated. Next, find error nodes and making the process recursive and adaptive. While considering these nodes that are not pre-defined can be located and can be assigned with functionality as a new originator based on the probability. If the probability of occurrence is too low then sensor functionality can be enhanced based on neighboring activities leading to multicast delivery with forwarding packets at much higher transmission rate. This supports normal delivery rate in multi-hop transmission. Hence, unicast and multicast delivery can be achieved at much simpler process using the LA-ANA based architecture at the MAC layer of the protocol stack.

The timing diagram shown in Fig. 5 is for ZigBee environment. The packet sent from the source is with host controller wherein intermediate nodes I_i and I_j are involved. The retransmission, successful transmission and acknowledgement availability is provided in timing diagram. The dotted lines in nodes I_i and I_j represents presence of nodes in case of node failure with either I_1 or I_2 . This complete setup provides an autonomic network based architecture for a ZigBee environment.

6 Simulation and Performance Evaluation

6.1 Simulation Environment

The ZigBee operating range is at 2.4 GHz with 100 m range is selected. The power density of propagation limit is doubled due to increase in reception level at multi-range transmission to support multicast delivery. The value of 5 is chosen as a random number for phase 2 of path loss. The NS2 simulation environment is selected to build simulation environment with time of 50msecs. Protocol disturbed are MAC protocol with SNR bound reception and 20 dBm of total transmitted power.

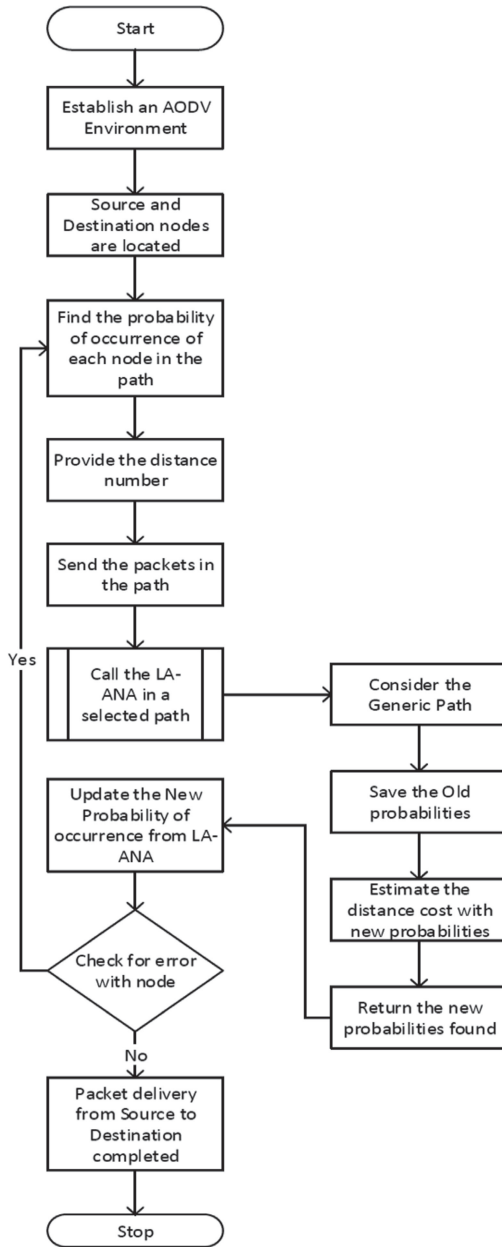


Fig. 4. Flowchart for LA-ANA and LACAS for a ZigBee

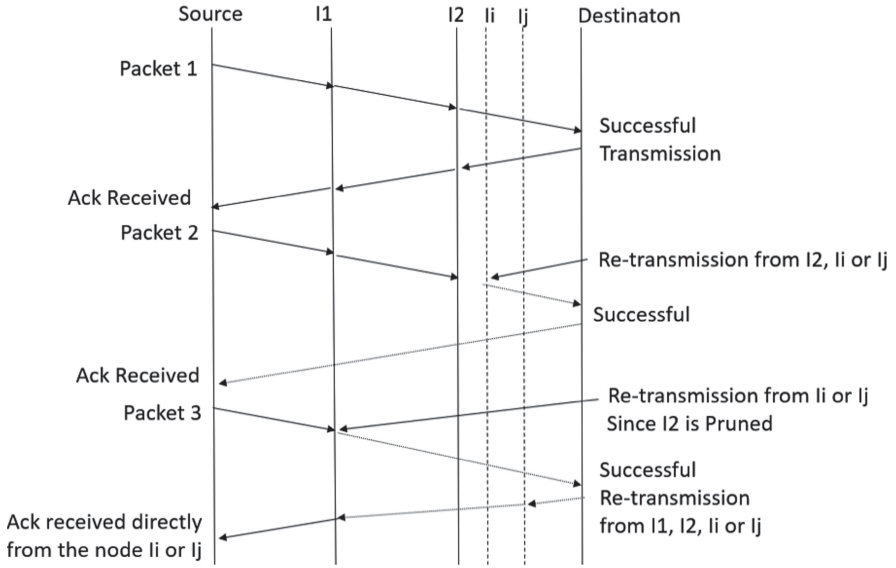


Fig. 5. Timing diagram between active and sleep nodes

6.2 Performance Analysis

The packet delivery and rate of change in probabilities of occurrence of nodes in shortest path chosen play a vital role in increasing throughput. Figure 6 shows the throughput of LA-ANA based network compared with LACAS network. There is substantial increase in throughput and is around 25% at larger density nodes. The throughput has reduced not less than 50% while involving 1000 nodes in a larger density dynamic environment.

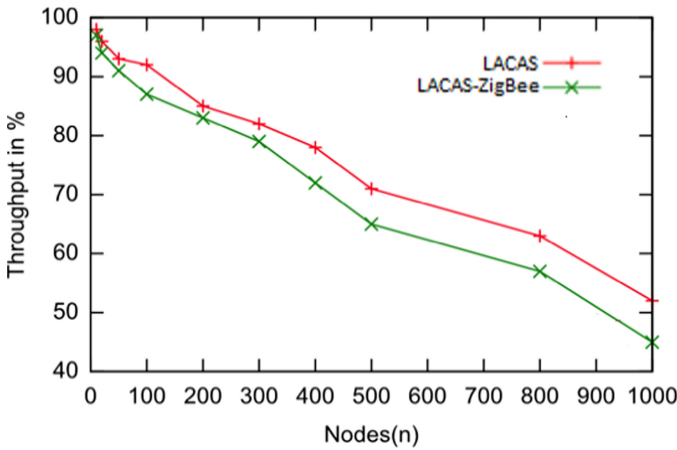


Fig. 6. Throughput

Hence, provides the users with LACAS-ZigBee algorithm capability in handling larger density nodes.

Figure 7 and Fig. 8 shows unicast and multicast delivery in LACAS-ZigBee and is better than the LACAS environment. This is due to congestion control at MAC layer and large density nodes that is considered in our scenario. There is 20% improvement in unicast delivery and around 15% in multicast delivery ratio. This substantial increase with delivery ratios is due to local automate that considers probability of occurrence of each node with its active and sleep nodes in a routed path. Thus, providing a stable design for designing ZigBee environment.

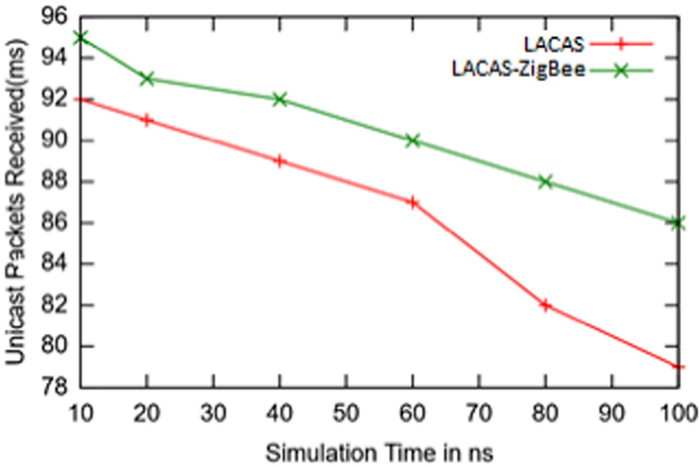


Fig. 7. Delivery of packets using unicast.

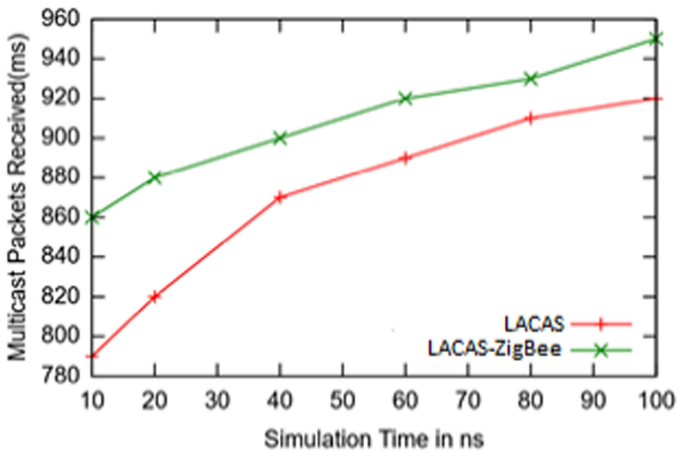


Fig. 8. Delivery of packets using multicast.

7 Conclusions

The cascode architecture is deployed for a ZigBee based dynamic environment. The process involves adaptability in choosing active nodes in presence of failing neighboring nodes mainly grounded on probability of occurrence. It provides a controlled congestion mechanism with increased throughput leading to improved unicast and multicast delivery ratio between source and destination. Thus, applying for a larger denser network in a dynamic environment provides greater adaptability during transmission.

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