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Throughput Maximization for Wireless Multimedia Sensor Networks in Industrial Applications

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Abstract: In recent years, there has been growing interests in wireless sensor networks. Wireless sensor network is an autonomous system of sensor connected by wireless devices without any fixed infrastructure support. To meet the challenge paradigms of wireless sensor networks like Energy efficiency, Delay constraints, Reliability and adaptive mechanism the sensor nodes are enhanced with multimedia support. The Wireless multimedia sensor nodes (WMSN) enable to streamline the data that will control and monitor the industrial activities within the sensing area. The adaptive sleepless protocol will address the following issues: First, this protocol mainly designed for desired packet delivery and delay probabilities while reducing the energy consumption of the network. Second, this protocol is based on demand based dynamic sleep scheduling scheme for data communication. In this packets are transmitted through the cross layer interaction. In this cross layer interaction enables to reach a maximum efficiency.

Keywords: wireless sensor networks, cross layer design, Dynamic sleep scheduling, Asynchronous Energy Saving, Cross-layer interaction.

I. INTRODUCTION

A sensor network is one of the emerging areas of mobile networking. A Wireless Sensor Network (WSN) is a set of hundreds of micro sensor nodes with the capability of sensing, establishing wireless communication between each other and does computational and processing operations.

A Sensor node can sense, process, transmit packets and also locate the system. Sensor nodes are scattered in a sensor field, in which the sensor nodes are deployed. Wireless multimedia sensor networks aim to sense image, audio and video information which cannot be easily described by simple sensor nodes. Using WMSN can significantly enhance the capability of event description.

The protocol is achieved by a randomized routing algorithm, which adapts to traffic variations and channel conditions. IEEE 802.15.5 low-rate part is used in the mesh function of wireless sensor networks. This protocol eliminates the initial route discovery latency, saves memory space and reduces the communication energy.

A Wireless Sensor Network (WSN) consists of a base station that communicates with a number of wireless sensors through radio link. A base station may be a fixed node or a mobile node capable of connecting the sensor network to an existing communication infrastructure. The transmitted data is then presented to the system by the base station connection.

In this paper random path based routing is implemented. A mesh network allows any node in the network to transmit to any other node in the network that is within its radio transmission range. This allows multi hop communications where, an intermediate node can be used to forward the message to the desired node that is within the communication range.

II. RELATED WORKS

The Breath protocol is based on unicast routing, MAC and duty-cycling, which allow it to minimize the energy consumption of the network while ensuring a desired packet delivery end-to-end reliability and delay. In Breath protocol support the adaptation mechanism-MAC is used to random process. Random process means each node periodically wakeup, listen to the channel and then back to sleep again. Scheduling channel polling works with assigned slots and then go back to sleep. SPAN worked according to the result of routing algorithm. The sensor nodes are activated only the fraction of seconds. Breath designed to avoid moving metal obstacles and radio disturbance.Fixed routing table not provide flexibility .Each node, either transmitter or receiver does not stay in an active state all time .It goes to sleep for random amount of time, which depends on traffic and channel condition. Compare to IEEE802.15.4 both data packet and beacon packets transmitted same MAC. But CSMA/CA the channel activity using CCA. Breath protocols have rough knowledge of each node location. Wireless HART has implemented in the existing system but data was not considered about the power expenditure [1].

The shared nature of industrial wireless sensor networks (IWSNs) brings several advantages over established wired industrial monitoring and control systems, including self-organization, rapid deployment, flexibility, and inherent intelligent-processing capability[2].

Industrial applications concerning mobile subsystems make wireless technologies striking when wireless relations are included, dependability and timing requirements are considerably more difficult to meet, due to the difficult properties of the radio channels [3].

A routing and MAC protocol are clustered in WSNs. This provides robustness to surroundings. The energy and storage capacity efficient and it can be implemented on a large set of existing hardware platforms. It has self design capabilities and it can support the addition of beacon nodes.[6].

The tough requirements of sensor networks have lead to the design of cross-layer architectures. The protocols and algorithm of the MAC, network, transport and applications layers can activate in a cooperative way that disrupts the conservative data flow and the understanding of protocol layers.

Wireless sensor networks (WSNs) aim to collect sensed data in a variety of applications. It collects the Image, audio and video information. Two basic problems are focused in WMSN: (1) gathering data as possible within an expected network lifetime; (2) minimizing transmission delay within an expected network lifetime [4].

III. SYSTEM DESIGN

The purpose of developing this protocol is to provide the architectural support, it enables WPAN devices to endorse interoperable, constant, and scalable wireless mesh topologies. It goes to sleep for random amount of time, which depends on traffic rate and channel condition.

A. *Random Routing*

This process is fully dynamic. This protocol on demand based routing information. Depending on the arrival of beacon node the network structure does communication within the clusters. The updating communication and change in network is done parallely. Each cluster communication and network changes for both static and dynamic node based routing.

B. *Dynamic Sleep Scheduling*

In sleepless protocol is designed on demand based dynamic sleep scheduling scheme for data communication, depending on the node wake up or beacon node arrival rate are scheduled. At the time of beacon message arrival sensor nodes are activated. The On-demand Based routing protocol is a protocol to connect nodes in WSN. It is a routing protocol which is reactive or on demand based, meaning that it establishes routes as needed. The advantage of this method is obvious if only a few routes are required, since the routing overhead is less compared to the proactive method of establish the routes whether are needed or not.

C. *Protocol Design*

The protocol groups all N nodes between the clusters of nodes attached to the plant and the base station with h - 1 relay clusters. Data packets can be transmitted only from a cluster to the other cluster closer to the base station. Clustered network topology is supported by networks that require energy efficiency, since transmitting data during relays consumes less energy than routing directly to the sink. In a dynamic clustering method adapts the network parameters. In a cluster header is selected based on the energy levels for clustered environments.

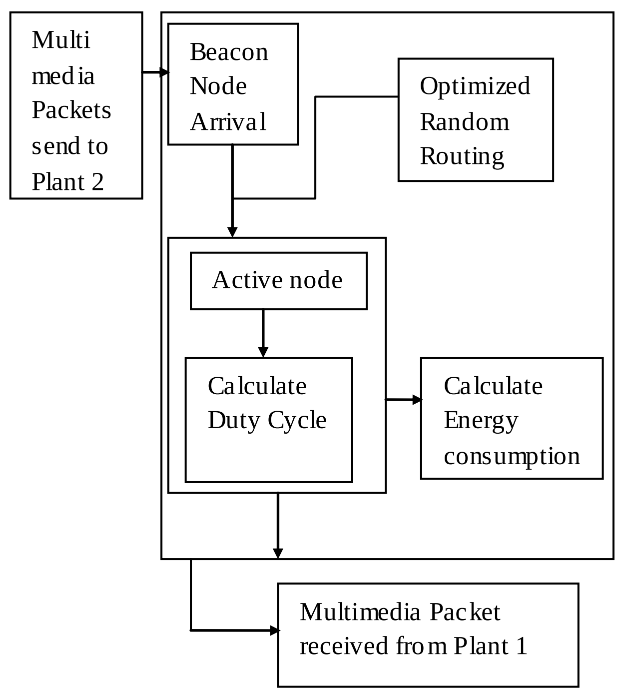

Fig. 1 Architecture of system design

D. Basic mesh functions

Mesh networking is a type of network where each node must not only capture and distribute its own data, but also serve as a relay for other nodes, that is, it must work together to spread the data in the network.

The design principle of the mesh algorithms for IEEE 802.15.5 focuses on the scalability, which encompasses hierarchy, localization, and minimal overhead. Each node is needed to store whichever routing table or link state information, which grows quickly along with the network size. Algorithms embedding network hierarchy for a improved scalability have been introduced, making use of dominating sets and clusters as seen in OLSR. However, the control overhead and energy spending for the maintenance of link state table or routing table at each node still falters in resource-constrained wireless sensor networks.

Tree structure provides a simple forwarding through the local link state provides alternative paths and optimized data forwarding. The link state information exchanges are done locally.

E. Multicasting

During data gathering the sensor nodes sense the data and generate a data packet, which is then transmitted to the base station or any other node. The multicast protocol is designed strongly coupled with the unicast protocol and relies on unicast, logical tree and local link state information.

It improves the performance of the system and makes sure the reliability; protocols are using multiple paths rather than a single path. Thus, alternate routes are established between a source and a destination sensor node. Periodical messages are exchanged to continue these alternate paths and these increase the network overhead.

F. Algorithm To Find Multi Hop Route

1. Beacon message Arrival M
2. if M Sent the new Multimedia Packet then
3. Drop the entire message
4. Continue for the next Beacon message
3. End if
4. Next Route Find Next Nodes (M destinations)
5. Assign Destination Nodes (M destinations, Next Route)
6. End

G. Energy Saving

Energy saving mechanism named a beacon Mode. The mode can be extended to multi-hop networks by creating a tree topology. Each device has to receive a beacon message from its parent device. Based on this method the active time is classified into, Asynchronous Energy Saving (AES) and Synchronous Energy Saving (SES).

Asynchronous Energy Saving: In AES each device has active duration and inactive duration. Asynchronous time schedule algorithm is used for data transmission. A beacon message is arrival a control frame is transmitted the wakeup notification to sensor node. Then the sensor nodes are wakeup and transmit the data packets. After the packet transmission sensor nodes are go to the inactive duration

H. Cross Layer Interaction

Cross-layer interaction is an escape from the pure waterfall model-like concept of the OSI communications model with practically exacting limitations between layers. Cross Layer Design is a way of information sharing between all the layers in order to obtain highest possible adaptively of any network. This is essential to meet the challenging Packet rates, higher performance and Quality of Services requirements for various real time applications. The cross interaction approach transports feedback dynamically via the layer limitations to enable the compensation. Cross layer interaction removes that condition limitations to allow communication between layers by permitting one layer to access the data of another layer to replace information and allow interaction. It helps to improve the end-to-end performance given networks resources. Sensor networks for image-based monitoring are very gorgeous since the communication requirements are less inflexible than video streaming monitoring applications.

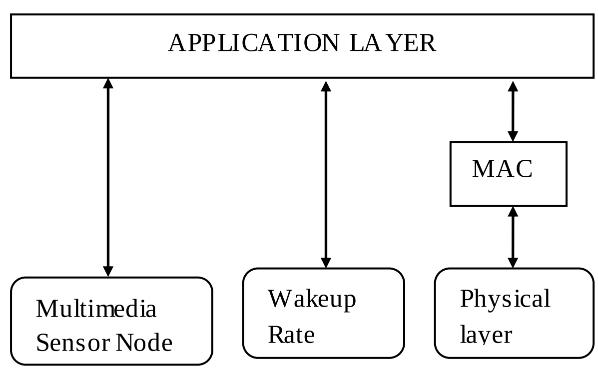

Fig. 2 Cross layer Architecture

IV. MODELING OF PROTOCOL

A. Tree Formation And Address Block Assignment

The tree formation starts with the first sensor node in the entire network designating itself as the root and beginning to accept association request from other node. After the first successfully associated, it determines whether to become a parent node which allows other nodes to join the network. After receiving topology update frames from all sensor nodes.

B. Protocol Behavior for Time-Varying Requirements

Performance of this protocol is based on the application requirements and estimation of the channel condition. There is a dynamic adaptability of reliability, packet delay, and energy consumption when the requirements are changed for given traffic rate and number of nodes. The average active time is depends on the average time of nodes which one active. Sleepless protocol adapts the network by considering the delay requirement variations. The average active time increases when the delay requirement changes due to a higher optimal wake-up rate.

To monitor the traffic in the higher layers of OSI applications duty cycle can be implemented. A duty cycle is defined as a time taken by an entity in an active state as a fraction of the total time under consideration.

C. Duty Cycle MAC

It is a mechanism used for controlling both packets sending and listening for a packet .It consists of two parts; Synchronous duty cycling and Asynchronous duty cycling. In Synchronous duty cycling the sender coordinates the neighbours wake up time. Asynchronous duty cycling based on preamble sampling. The receiver node wakes up periodically and checks if there is a transmission. The transmitter sends packet preambles by random access until the receiver wakes up.

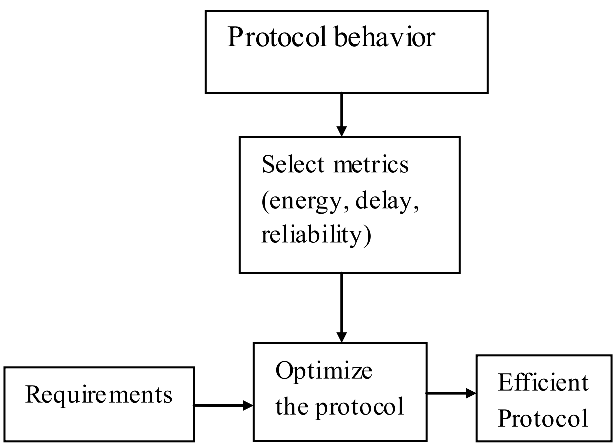

Fig. 3 MAC Design For WMSN

D. IEEE 802.15.5 WPAN

IEEE 802.15.5 MAC that targets providing mesh capabilities to both high-rate and low-rate wireless personal area networks. Low-rate mesh system is built on IEEE 802.15.4 MAC and high-rate mesh utilize IEEE 802.15.3 MAC.

The familiar features of both meshes include network initialization, addressing, and multihop unicasting. In addition, the low-rate mesh wires multicasting, reliable broadcasting, portability support, trace direction and energy saving task and the high rate mesh supports multihop time guaranteed service [2].

HR-WPAN mesh adapts two different types of routing techniques: tree-based self routing and enhanced server routing. In small-scale applications may use tree routing, in time-constrained multimedia applications use server-guided routing. In Sleepless adaptive protocol design server routing methods are used.

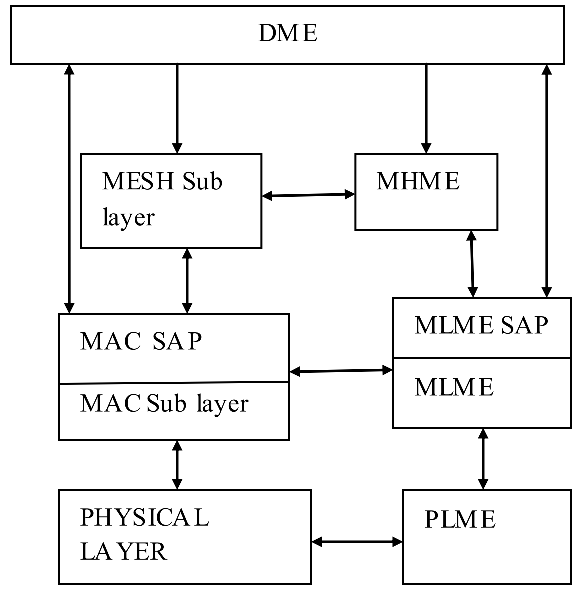

Fig. 4 Architecture of HR WPAN

E. Traffic Rate and Channel Estimation

Traffic rate and channel estimation has done by the base station.The probability model has been applied. Channel condition from every local sensor node will inform to the sink. It estimates by the signal of the beacon packet. After that comparison with the channel condition traffic rate to be changed.

V. SIMULATION ENVIRONMENT

Experiments are based on simulations using the NS2 network simulator. A sensor network is considered with 35 numbers of sensor nodes that are randomly distributed in the 200 * 200 m2 area, denoted as cluster-1 node, cluster -2 node, and cluster -3 node. The base station, with 'x' is located at point (100, 350). The performance of the proposed protocol is evaluated. The horizontal and vertical coordinates of each sensor are randomly selected between 0 and maximum value of the dimension. The size of the communication that nodes send to their cluster heads as well as the size of the message that a cluster head sends to the base station is set to 500 bytes.

Table 2. Simulation Parameters

Parameters	Values
Network Span	(0,0) to (200,200)
Number of nodes	35
E_I	1J
X(proportion of type-3 nodes)	0.5
Y(proportion of type-3 nodes)	0.3

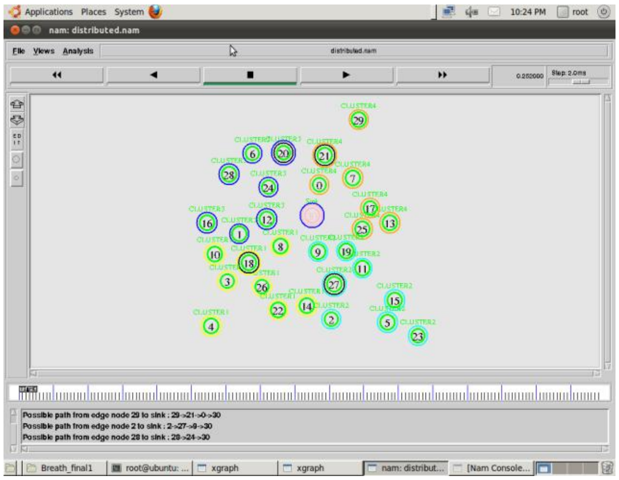

Fig. 5 Multicast routing

Fig 5 shows the multicast routing of the network environment. Multimedia sensor nodes are placed. Beacon messages are arrival. Sensor nodes wake up and select the path using multi hop routing algorithm.

VI. RESULTS AND DISCUSSION

The performances of Sleepless protocol in industrial control application are discussed as follows.

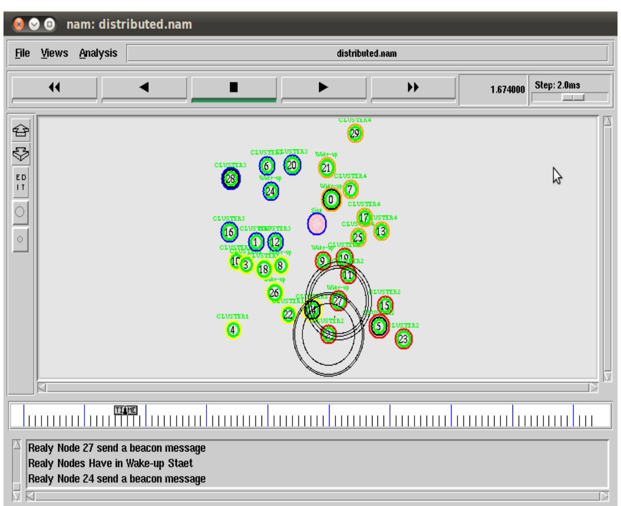

Fig. 6 Network Architecture

A wireless sensor network is formed which consists of multimedia sensor nodes. The cluster head selection is done based on the energy level of each type of node followed by clustering of the sensor nodes. The cluster head gathers information from the cluster members and forward them to the Base station.

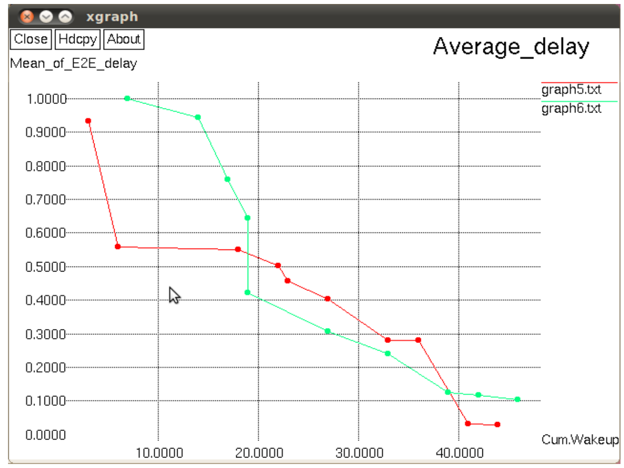

Fig. 7 Delay Vs Wakeup rate

Fig 7 shows minimum delay that the application can set is achieved by considering a wake-up rate per cluster. This minimizes the waiting time before getting a beacon message. Hence, by summing the delays of the CSMA/CA state and physical limit of the wireless channel the total delay value is found.

The network by considering the delay requirement variations. The average active time increases when the delay requirement changes due to a higher optimal wake-up rate. At the same time, packet delay decreases while the average active time increase. Wakeup rate means the nodes are turns its active state and broadcasts a beacon indicating its location. Then the nodes are goes to listen state and it listen to the channel. Listen state means the node starts a fixed timer duration that must enough to receive a packet.

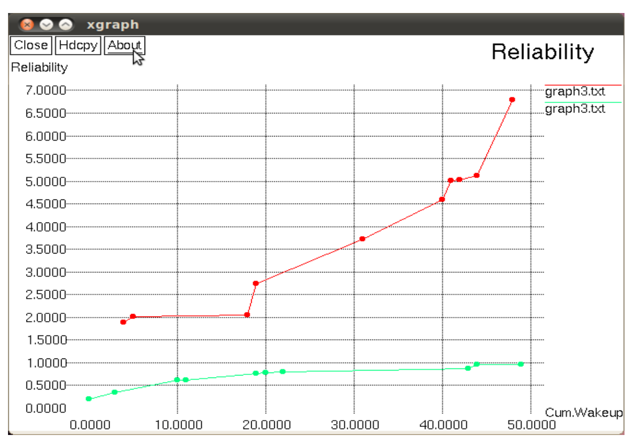

Fig. 8 Reliability Vs Wake rate

Fig 8 shows probability of successful packet reception during a single-hop transmission from cluster. They allow to compute the probability of successful transmission in CSMA/CA. This probability helps to find the value of successful transmission of one packet. This constraint is a function of the minimum desired reliability is required.

The node discards the data packet and goes to the Calculate Sleep State. If the channel is clear surrounded by the upper limit number of attempts, the node transmits the data packet by means of a suitable level of radio power and goes to the Calculate Sleep State.

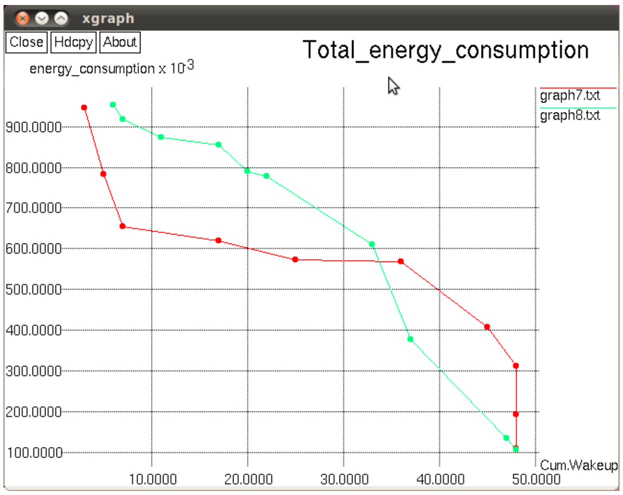

Fig. 9 Energy Consumption Vs Wakeup Rate

Fig 9 shows total energy for transmission and reception of data packets and the energy consumption for wake-up, listening, and beaconing during at a time. After the node wakes up, it transmits a beacon to the next cluster. CSMA state means the sensor node switches its ratio to hear the data channel and it tries to send packets to the next cluster.

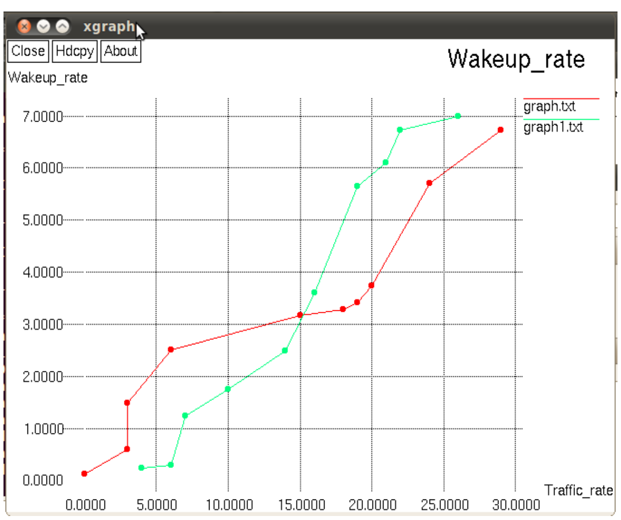

Fig. 10 Traffic rate Vs Wake up rate per node

Fig 10 shows the wakeup rates that minimize the total energy consumption and approximated wake up rate obtained by 30 nodes for different numbers of traffic rates. Wake-up State means the node turns its beacon channel on, and broadcasts a beacon representative its location. Then, the sensor nodes are switches to listen to the data channel, and it goes to the Idle Listen State. The node starts a active state of a fixed duration that must be long enough to receive a packet. If the nodes are going to the inactive duration before any data packet is received, then calculate the Sleep State.

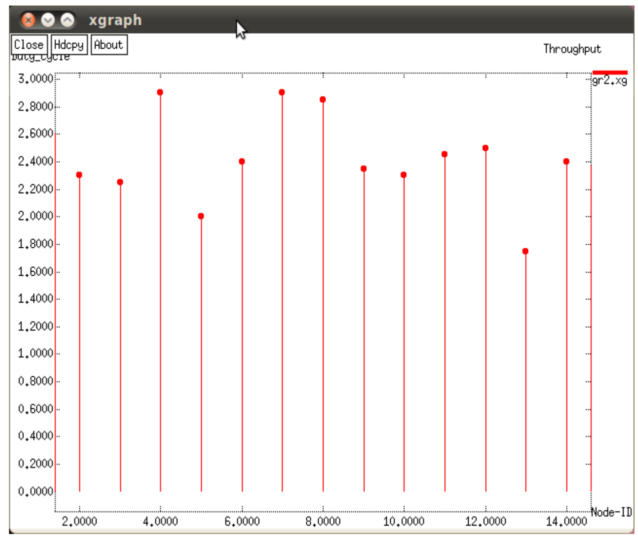

Fig. 11 Duty Cycle Vs Traffic Rate

Fig 11 shows the duty cycle of each node. The distribution of duty cycle among all nodes of the network achieved. Duty cycles are uniformly distributed with the advantages of network life time. Ensuring a duty cycle for the other protocol implementation comparable with IEEE 802.15.5 would be very detrimental with respect to the reliability.

VII. CONCLUSION

An Adaptive Sleepless protocol is based used to find reliability and delay requirements in wireless sensor networks for controlling and monitoring the industrial applications. The protocol considers duty cycle, routing, MAC, and physical layers all together to maximize the lifetime of sensor node. By this account the trade-off between energy consumption and delay constraint are calculated and monitored.

In future a new IEEE standard, IEEE 802.15.5 WPAN mesh, is used in the protocol. Both the LR and HR parts introduce the basic mesh functions including tree formation, allocation of address blocks, and mesh routing. It could be implemented for mesh networks such as coexisting ad hoc and wireless sensor networks. Communication can be promoted between HR-WPAN and LR-WPAN.

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