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802.11KT MAC Protocol: A Small Delay and Low Cost Wireless Network Protocol for Ad-hoc Robot Wireless Communication in Industrial Application

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Abstract*—Wireless communication and wireless communication protocol play an important role in mobile robot system. Wireless protocol enables mobile robot system to address many real world industrial applications. 802.11KT MAC protocol is a modified wireless network protocol independent of topology of nodes that aims to provide low-cost and small delay wireless network protocol for industrial application. For the industrial application areas like assembly line and manufacturing line in big industry, Ad-hoc robot wireless network system based on 802.11 MAC protocol is used. 802.11 MAC protocol plays a important role for networking because of its cost, which is low as compared to the other networking. Moreover the MAC protocol provides higher rate of data transfer. This paper is subjected to comprehensive performance analysis between IEEE 802.11 MAC protocol and our modified MAC 802.11KT protocol with AODV routing protocol in grid topology Ad-hoc robot wireless network using Network Simulator-2(NS-2).Various important performance metric such as Total packet generated, Total packet received Total dropped packets, Average end to end delay, Packet Delivery Ratio Vs. Packet size are investigated. Protocols are simulated using NS-2 simulator. It is observed that MAC 802.11KT protocol outperform IEEE 802.11 MAC protocol and it is suitable as low cost and small delay wireless network protocol for Ad-hoc robot wireless network for industrial applications .

***Keywords* - AODV, IEEE 802.11, NS-2 Simulation**.

I. INTRODUCTION

As VLSI technology advances and computing power grow in the past decades, robots became more and more intelligent, robust and power-efficient. They are required to handle more and more so-called teamwork. It means that they must be developed to possess the capability of constructing a network and performing cooperative work. A key driving force in the development of cooperative mobile robotic systems is their potential for reducing the need for human presence in dangerous applications such as the disposal of toxic waste, nuclear power processing, fire fighting, military or civilian search and rescue missions, planetary exploration, security, surveillance, and reconnaissance tasks. In these cases, wireless communication based on IEEE 802.11 MAC protocol provides the low cost solutions for mobile robot networks to cooperate efficiently. In the early robot wireless communications, infrared technology was applied in a large scale [Kahn 1997; Hsu1995] because of its low cost. But infrared wave cannot pass through obstacles (e.g. wall) and infrared systems have poor communication rate and quality (rain effect) design of mobile robot communication. Robots can communicate with others by RF point-to-point link or broadcasting mechanism. The cost of laying wire to large numbers of robots in assembly line and manufacturing line areas is prohibitively expensive and hence a very important requirement for these networks is to minimize the infrastructure costs. Recent technologies have demonstrated an alternative approach by building Ad-hoc robot l wireless network prototypes using IEEE 802.11 equipment. IEEE 802.11 equipment is highly commoditized and goes a long way. We have considered the principal of mobile ad-hoc network for grid type topology for Ad-hoc robot network for industrial application. A Mobile Ad hoc Networks represents a system of wireless mobile Ad-hoc robot nodes that can freely and dynamically self-organize into arbitrary and temporary network topologies, allowing robots to seamlessly communicate without any pre-existing communication architecture. Each mobile robot node in the network also acts as a router, forwarding data packets for other nodes. A central challenge in the design of ad hoc robot networks is the development of dynamic protocols that can efficiently find routes between two communicating Ad-hoc robot nodes. The goal is to carry out a systematic performance & comparative study of 802.11 MAC & our modified MAC protocol i.e.802.11KT protocol for Grid scenario topology for ad hoc robot networks in industrial application. Moreover performance analysis & comparative study is based on varying data packet size in the Mobile Ad Hoc Robot Network in grid topology within area of assembly line and manufacturing line of big industry. The rest of the paper is organized as follows: The work contributed in this area is provided in section II. The AODV, 802.11 MAC protocol & 802.11KT MAC protocol description is summarized in section III. The simulation environment and performance metrics are described in Section IV .The simulation results and observation are described in section V and the conclusion is presented in section VI.

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II. RELATED WORK

A Several researchers have done the qualitative and quantitative analysis of Ad Hoc Routing Protocols by means of different performance metrics. They have used different simulators for this purpose. *Rafi U Zamam et.al* [1] studied & compared the performance of DSDV, AODV and DSR routing protocols for ad hoc networks using NS-2 simulations. In this paper, author observed that the competitive reactive routing protocols, AODV and DSR, both show better performance than the other in terms of certain metrics. It is still difficult to determine which of them has overall better performance in MANET. *Vahid Garousi et.al* [2] studied an analysis of network traffic in ad-hoc networks based on the DSDV protocol with an emphasis on mobility and communication patterns of the nodes. In this paper, he observed that simulations measured the ability of DSDV routing protocol to react to multi-hop ad-hoc network topology changes in terms of scene size, mobile nodes movement, number of connections among nodes, and also the amount of data each mobile node transmits. *Das,S.R., Perkins,C.E. et.al* [4] studied & compared the performance of DSDV, AODV and DSR routing protocols for ad hoc networks using NS-2 simulations. In this paper, they observed that DSDV uses the proactive table-driven routing strategy while both AODV and DSR use the reactive on-demand routing strategy. Both AODV and DSR perform better under high mobility simulations than DSDV. High mobility results in frequent link failures and the overhead involved in updating all the nodes with the new routing information as in DSDV is much more than that involved AODV and DSR, where the routes are created as and when required. *Chao,C-M. et.al [5]* studied the performance comparison based on packet delivery fraction and normalized routing load. In the future, extensive complex simulations could be carried out in gain a more in-depth performance analysis of the ad hoc routing protocols. This would include delay of data packet delivery and performance comparison on location-based ad hoc routing protocols.

III. AD-HOC ROBOT COMMUNICATION NETWORK

Ad-hoc robot wireless networks provide the networking infrastructure to support the quality of service needs such as bandwidth, latency and reliability, small end to end delay, more packet delivery ratio of robot communications. They must support: quick reconfiguration of mobile robot nodes using 802.11 protocol, mobility management using mobile IP, AODV routing protocol, service level agreement (SLA) management. Figure 1 gives a layered model of mobile robot networking. It has transport, network, data link, and physical layers. In the system of cooperative multiple mobile robots, communications among them are critically important. Each robot should exchange the information collected through its sensors and negotiate its task scheduling with other robots. These robotic communications are executed through the random access telecommunication among mobile robots and from the remote control room. .

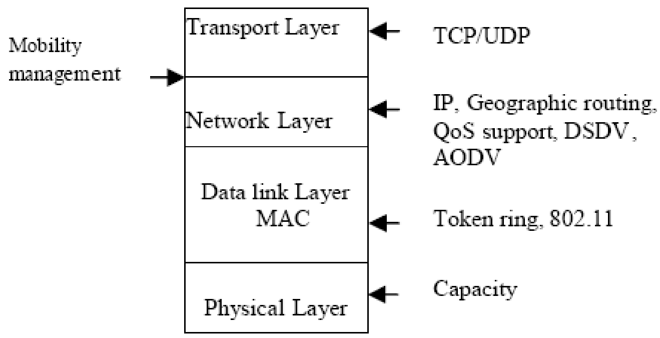

fig.1 Mobile robot networking layered model.

IV. DESCRIPTION OF THE PROTOCOLS

This section briefly describe the key features of 802.11 protocol, AODV protocol & modified 802.11KT MAC protocol that being studied in this paper..

A) IEEE 802.11 Mac Protocol

The basic access method in the IEEE 802.11 MAC protocol is DCF, which is based on carrier sense multiple access with collision avoidance (CSMA/CA). Before starting a transmission, each node performs a backoff procedure, with the back off timer uniformly chosen from [0, CW − 1] in terms of time slots, where CW is the current contention window. When the backoff timer reaches zero, the node transmits a DATA packet. If the receiver successfully receives the packet, it acknowledges the packet by sending an acknowledgment (ACK). If no ACK is received within a specified period, the packet is considered lost; so the transmitter will double the size of CW, choose a new backoff timer, and start the above process again. When the transmission of a packet fails for a maximum number of times, the packet is dropped. To avoid collisions of long packets, the short request to send/clear to send (RTS/CTS) frames can be employed. Note that the IEEE 802.11 MAC also incorporates an optional access method called PCF, which is only usable in infrastructure network configurations and is not supported in most current wireless cards. In addition, it may result in poor performance.

B) Ad Hoc On-Demand Distance Vector (AODV)

AODV is a distance vector type routing. It does not require nodes to maintain routes to destination that are not actively used. As long as the endpoints of a communication connection have valid routes to each other, AODV does not play a role. Same as DSR, the Protocol is also composed of route discovery and route maintenance. The protocol uses different messages to discover and maintain links such as ROUTE REQUEST, ROUTE REPLY and ROUTE ERROR. This message types are received via UDP, and normal IP header processing applies. AODV uses a destination sequence number for each route entry. The destination sequence number is created by the destination for any route information it sends to requesting nodes. Using destination sequence numbers ensures loop freedom and allows

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knowing which of several routes is fresher. Given the choice between two routes to a destination, a requesting node always selects the one with the greatest sequence number. When a node wants to find a route to another one, it broadcast a ROUTE REQUEST to all nodes in the network until either the destination is reached or another node is found with a fresh enough route to the destination.

Fresh enough route is a valid route entry for the destination whose associated sequence number is at least as great as that contained in the ROUTE REQUEST. Then a ROUTE REPLY is sent back to the source and the discovered route is made available. For route maintenance, nodes that are part of an active route may offer connectivity information by broadcasting periodically local Hello messages (special ROUTE REPLY message) to its immediate neighbors. If Hello messages stop arriving from a neighbor beyond some given time threshold, the connection is assumed to be lost. When a node detects that a route to a neighbor node is not valid it removes the routing entry and sends a ROUTE ERROR message to neighbors that are active and use the route. This is possible by maintaining active neighbor's lists. This procedure is repeated at nodes that receive ROUTE ERROR messages. A source that receives a ROUTE ERROR can reinitiate a ROUTE REQUEST message.

C) *MAC 802.11KT protocol*

The MAC 802.11KT protocol modifies the IEEE 802.11 RTS/CTS handshake on transmitter (RTS) and receiver (CTS), respectively. This protocol modifies IEEE 802.11 for various inter frame space, contention window for minimum and maximum size to obtain high system throughput and small end to end delay. This protocol modifies the security mechanism, power management mechanism, synchronization mechanism, association and reassociation mechanism of nodes with access point. It also modifies management information base required for network management purpose for external entities. Our goals is to obtain the maximum throughput, less numbers of data packets dropped, high packet delivery ratio and small end to end delay by the 802.11KT protocol as compared to that of the conventional 802.11 system. Numerical evaluation of the proposed analysis framework indicates that the 802.11KT protocol system can provide a significant increase in throughput and decrease in end to end delay for any type of topology in MANET. Hence it is very much suitable as low cost wireless protocol in ad-hoc robot network in big industry.

V. SIMULATION ENVIRONMENT

A. *Simulation Model*

This section have given the emphasis for the simulation of performance of IEEE 802.11 MAC protocol and 802.11KT MAC protocol with AODV as routing protocol varying the data payload of mobile ad-hoc nodes. The simulations have been performed using network simulator NS-2 [12]. The network simulator ns-2 is discrete event simulation software for network simulations which means it simulates events such as sending, receiving, forwarding and dropping packets. The latest version, ns-allinone-2.34, supports simulation for routing protocols for ad hoc wireless networks such as AODV, TORA, DSDV, and DSR. Ns-2 is written in C++ programming language and Object Tool Common Language (OTCL). Although ns-2.34 can be built on various platforms, we chose a Linux platform [FEDORA 7] for this paper, as Linux offers a number of programming development tools that can be used along with the simulation process. To run a simulation with ns-2.34, we have written the simulation script in OTCL, got the simulation results in an output trace file. The performance metrics are calculated using AWK file and the result graphically visualized. Ns-2 also offers a visual representation of the simulated network by tracing nodes movements and events and writing them in a network animator (NAM) file.

B. *Simulation Parameters*

We consider a Ad-hoc robot network of nodes placing within a 1000m X 1000m area. The performances of IEEE 802.11 MAC and 802.11KT MAC are evaluated by varying the network data payload and keeping the mobility of mobile Ad-hoc robot nodes constants. Table 1 shows the simulation parameters used in this evaluation.

TABLE 1.PARAMETERS VALUES FOR SIMULATION

Simulation Parameters	
Simulator	ns-2.34
MAC Protocols	802.11,802.11KT
Simulation duration	150 seconds
Simulation area	1000 m x1000 m
Number of nodes	6x6
Transmission range	250 m
Movement model	Grid topology
Routing Protocol	AODV
Data Packet size in bytes/packets	512,1000,1500.2000.2500.3000
Packet rate	4 packets/sec
Traffic type	CBR (UDP)

C. *Performance Metrics*

While analysing IEEE 802.11 MAC protocol and 802.11KT MAC with Ad-hoc robot mobile node in grid topology for industrial applications, we focused on performance metrics such as Generated Packets, Received Packets, Packet delivery ratio, Total dropped packets, Average end to end delay Vs. data packet size.

VI. SIMULATION RESULTS & OBESRVATION

The simulation results are shown in the following section in the form of line graphs. The performance of IEEE 802.11 MAC and 802.11KT MAC protocol are done based on the data packet size of the robot node. The perform matrix consists of parameters like Total packets generated, Packets dropped, Packets Delivery ratio & Average End to End delay,. "Fig. 2" shows the creation of 36 numbers of robot mobile nodes in assembly line and manufacturing line in big industry in grid topology. "Fig.3" highlights the control of Ad-hoc robot nodes in the industry with the data packet size

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of 500 bytes/packet. It is observed that the source nodes in the control room are communicating with other robot nodes. The data packet size consists of the information about the activity of ad-hoc robot nodes.

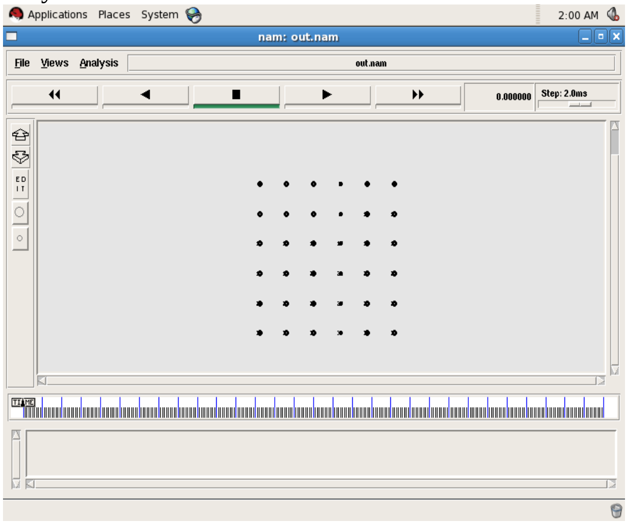

Fig 2. 36 No. Of Robot Nodes in Assembly Line in Grid Topology

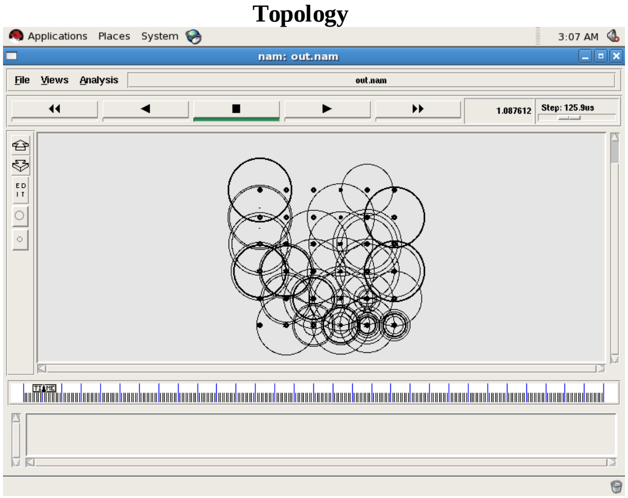

Fig 3. Ad-Hoc Robot Nodes with Packet Size of 500 Bytes/Packet

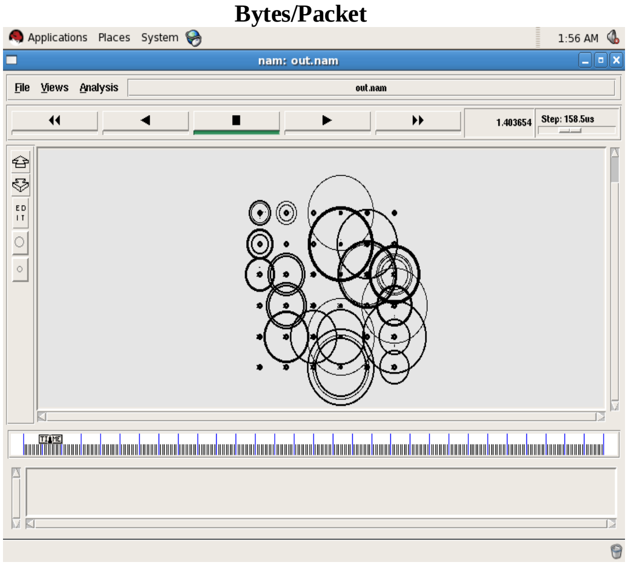

Fig 4. Ad-Hoc Robot Nodes with Packet Size of 1000 Bytes/Packet

"Fig. 4" highlights control of ad-hoc robot activity in working area on assembly floor and manufacturing floor with data packet size of 1000 bytes/packet from the source node. Nodes are communicating with each other with good synchronisation between them.

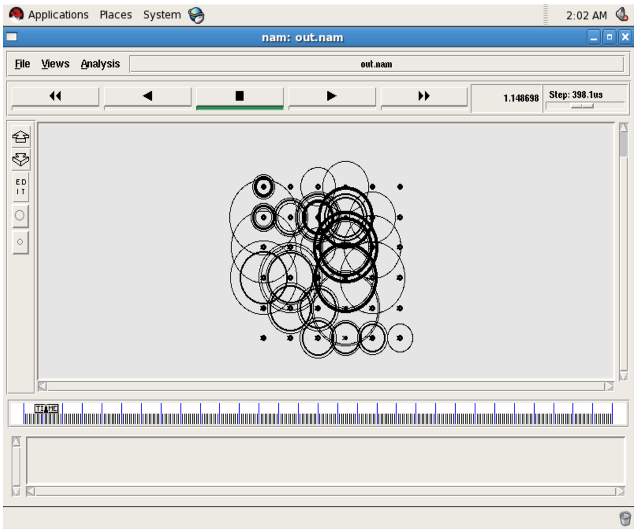

Fig 5.Ad-Hoc Robot with Packet Size of 1500 Bytes/Packet

"Fig.5" illustrates data packet communication between ad-hoc robot nodes at data packet size of 1500 byte/packet in assembly line working area. It represents that at this data packet rate, robot nodes are controlled from the source control room maintaining synchronisation between them. "Fig.6" highlights the control of movement of ad-hoc robot mobile nodes with data packet size of 2500 bytes/packet in industrial application area. It illustrate that at high data packet size, ad-hoc robot nodes are controlled from the source control room with proper coordination between them. There is a perfect synchronisation and communication between them. "Fig. 7" illustrates the communication of data packet amongst various ad-hoc robot nodes with a data packet size of 3000 bytes/packet. It highlights those nodes able to communicate with each other with minimum data packets dropped.

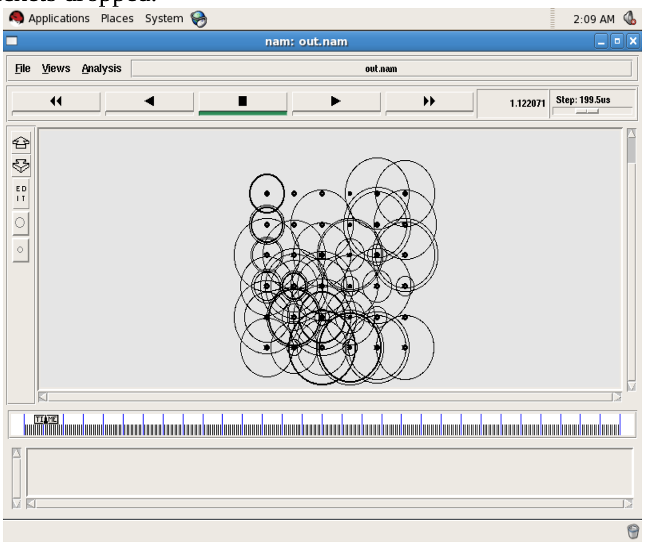

Fig 6.Ad-Hoc Robot Nodes with Packet Size Of 2000 Bytes/Packet

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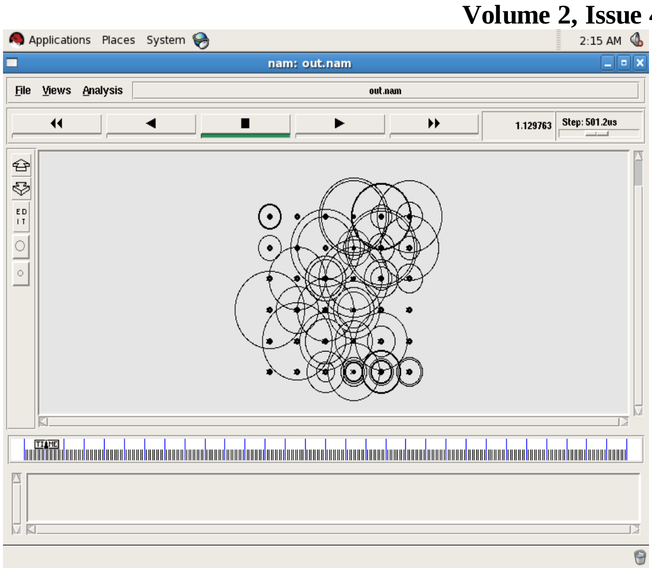

Fig. 7.Ad-Hoc Robot Nodes with Packet Size Of 2500 Bytes/Packet

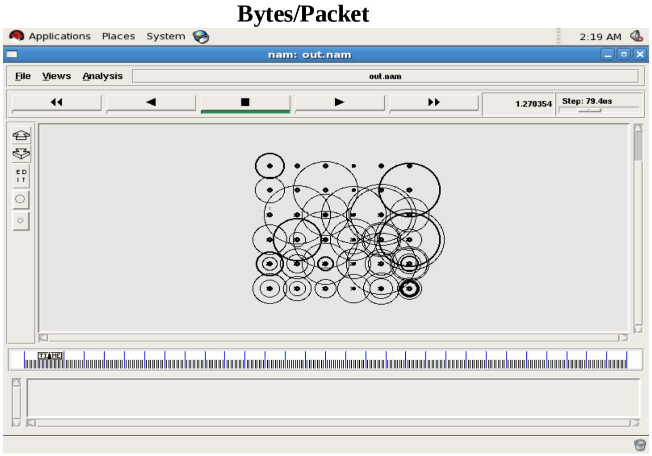

Fig. 8.Ad-Hoc Robot Nodes with Packet Size Of 3000 Bytes/Packet

"Fig. 8" illustrates the control of ad-hoc robot operation from distance source control room of 36 nodes in assembly line and manufacturing line in big industrial industry area with a data packet size of 3000 bytes/packets. At such high data packet size, mobile nodes are maintaining proper synchronisation with minimum numbers of data packet dropped, minimum end to end delay and high packet delivery ratio.

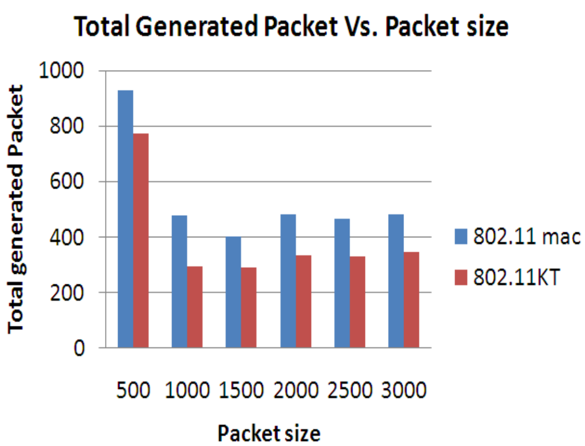

Fig 9.Total Generated Packets vs. Packet Size

"Fig. 9" highlights the relative performances of IEEE 802.11 MAC protocol and 802.11KT MAC protocol for Generated Packets with varying packet size of ad-hoc robot nodes. From figure it is observed that data packet size required to transfer information and to control the operation of robot nodes from source control room to destination ad-hoc robot node is small for 802.11KT MAC protocol than IEEE 802.11 MAC protocol. This saves approximately 15% of power consumption of transmitter for 802.11KT protocol than IEEE 802.11 MAC protocol. This makes robot operation as energy efficient.

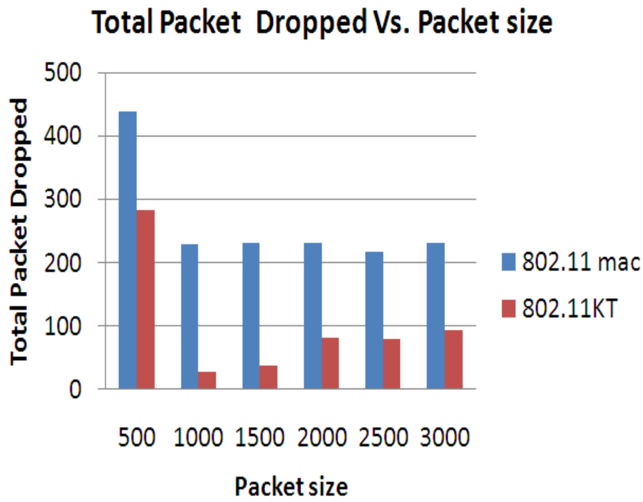

Fig 10. Total Packet Dropped Vs. Packet size

"Fig.10" highlights the relative performance of IEEE 802.11 MAC protocols and 802.11KT MAC protocol for Total Packet Dropped with varying packet size of Ad-hoc robot nodes. From figure it is observed that 802.11KT MAC protocol provides better synchronisation and hence communication between robot nodes than IEEE 802.11 MAC. Therefore, there is small numbers of data packet dropped for 802.11KT MAC protocol. This helps in providing better redundancy of information transmission between Ad–hoc robot nodes of industrial application area and complete information is communicated between them and better control of robotic operation can be obtained from the control room. This results in saving of approximately 80% of data packet and saving of power of transmitter."Fig.11" highlights the relative performance of IEEE 802.11 MAC protocol and 802.11KT MAC protocol for Packet Delivery Ratio with varying packet size of ad-hoc robot nodes. From figure it is observed that 802.11KT protocol have better performance over IEEE 802.11 MAC protocols in term of Packet Delivery Ratio. 802.11KT MAC protocol have better synchronisation between nodes, less number of data packets dropped and delivered more data packets to the destination than IEEE 802.11 MAC protocols.Hence,802.11KT protocol have more throughput of system network than IEEE 802.11 MAC protocol. The indicate that 802.11KT MAC protocol have approximately 20% more Packet Delivery ratio than IEEE 802.11 MAC protocol

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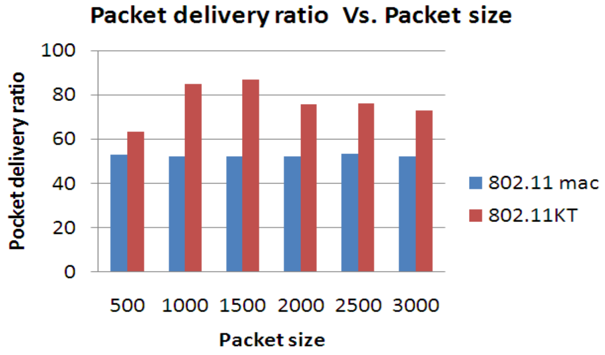

Fig.11. Packet Delivery Ratio vs. Packet size

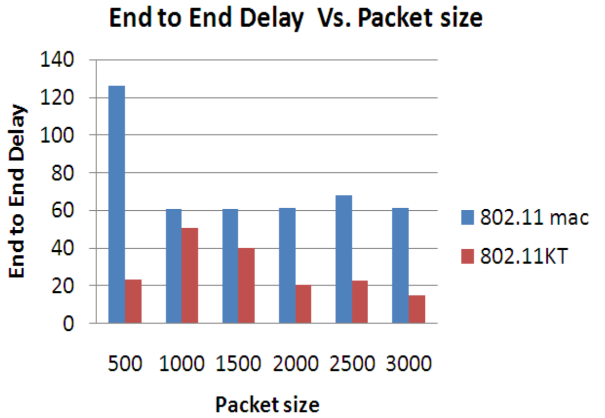

Fig.12. End to End delay Vs. Packet size

"Fig.12" highlights the relative performance of 802.11KT protocol and IEEE 802.11 MAC protocol for Average End To End delay with varying packet size of ad-hoc robot nodes for industrial application.. From figure it is observed that 802.11KT MAC protocol have better performance over IEEE 802.11 MAC protocol in terms of Average End To End delay. Beacon frame of 802.11KT MAC protocol provides efficient synchronization than IEEE 802.11 MAC between nodes. This result in better data transfer with minimum time required and improves the end to end delay. Source control room which actuate, communicate and control various operation of various robots on assembly line and manufacturing line working areas required small time to handle various ad-hoc robots. The result indicate that 802.11KT MAC protocol have approximately 75% small End to End delay as compared to IEEE 802.11 MAC

VI. CONCLUSION

Robot is useful to perform various operations in industry. They are used for operation in assembly line and manufacturing line and they are required to perform operation in hazardous condition like furnace .Robot operation should have minimum delay and low power consumption The work presented in this paper gave an overview of relative performance comparison of available IEEE 802.11 MAC protocol and 802.11KT MAC protocol for industrial application area in assembly line and manufacturing line of big industry area in grid topology. Simulation performance analysis indicate that 802.11KT MAC protocol have better performance than IEEE 802.11 MAC in terms of Total Data Packets generated, Total Packet Dropped, Packet Delivery Ratio and End to End delay parameters with varying packet size of ad-hoc robot node. 802.11KT MAC protocol have better synchronization mechanism, efficient link layer recovery mechanism, less numbers of collision and less inter link interference than IEEE 802.11 MAC and hence it outperform IEEE 802.11 MAC protocol. Therefore it is more suitable as small delay and low cost wireless network protocol for ad-hoc robot control operation in big industry. Hence the dominant cost of constructing a wireless network based on 802.11KT MAC protocol will be less to provide better wireless services for ad-hoc robot control operation in industry.

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