Time Slot Schedule based Fast Graph Rotuing in TDMA based Wireless Industrial System

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***Abstract*— The Graph Routing is one of routing method which used in the wireless factory automation system standard, ISA100.11a based Wireless Sensor Network (WSN). However, the generating rule of this graph is not specific and have to be the specific the graph generation method considering the reliability and real-time services. This paper proposed the graph generation method consider about schedule of superframe time slot that communicate quickly from source to destination in ISA100.11a network. Through this, the cognition speed about the urgent situation including the fire, prevention of crime, and etc can be enhanced and it can control rapidly. About reduction of the End-to-End Delay through graph which is put through C / C++ and comprises the topology of a network and time slot of a superframe and is generated according to the proposed algorithm and the other factors are measured. The transfer speed enhancement at the Wireless Industrial System is proved.**

Keywords-ISA100.11a, Wireless Sensor Network, Graph Routing,End-to-End Delay

I. INTRODUCTION

The ISA 100.11a[1] standard received the certification of the ANSI (American National Standard Institute) with the wireless sensor network standard for the industrial automation system and process control established at the ISA (International Society of Automation). It is the de facto standard that more than 100 million ISA standard products are installed and used in the place of industry. There is the weakness that the place of industry is full with the cable and wired equipment so there are many problem to maintain and repair and modify processing. ISA is the wireless sensor network standard which is suitable to use in the place of industry which is designed in order to follow IEEE 1451 (smart sensor) and ISO / ISO 7 hierarchical layer.

In the ISA100.11a network, the reliability is one of the most important factor. For guaranteeing the network reliability, the graph having a multiple paths is used. So, the various transmission route from a source to a destination is guaranteed. Since using the TDMA based MAC protocol and channel hopping, the network packet collision is prevented. By these methods, ISA100.11a standard is guaranteed a reliability. However, ISA100.11a is a monitoring system of the industrial system, the real-time is the important factor as the reliability. In the current standard, since the transfer rate or the throughput of the network is not considered.

In this paper, we propose the graph generation method for minimizing the End-to-End delay in order to notice rapidly the urgent situations including the fire or crime, and etc. In the next section, it introduces about related works with the ISA100.11a routing standard. In chapter 3, proposed concept of this paper and fast graph generation algorithm are introduced. In chapter 4, the superiority of the paper introducing the transfer rate using C / C++ and experimental result about the throughput improvement and energy efficiency and reliability is proved. In chapter 5, it comes to the conclusion and the guide about a task is guided.

II. BACKGROUND

A. ISA100.11a Routing

The ISA100.11a standard is the sensor network service based on 802.15.4 Datalink Layer standard. In ISA100.11a, the Mesh-under routing at layer 2 is used for the sensor network efficiency. A routing is supported from the DROUT sub-header of the Data Link Subnet Layer existing between the Data Link Layer and Network Layer. In ISA100.11a routing mechanisms are mingled source routing with graph routing. The Source routing is basic routing method of ISA100.11a standard, nodes are communicated with system manager through the pre-defined alternative route. The system manager advertise to the node route of source to destination and the node comprises the DROUT Sub-header using the received routing information.

octets	bits							
	7	6	5	4	3	2	1	0
1 octet	Compress=0	Priority (Unsigned4)				DlForwardLimit (Unsigned3)		
0-1 octet	DlForwardLimitExt (Unsigned8)							
1 octet	N (number of entries in routing table; Unsigned8)							
2*N octets	Series of N GraphIDs/addresses (Unsigned16, LSB)							

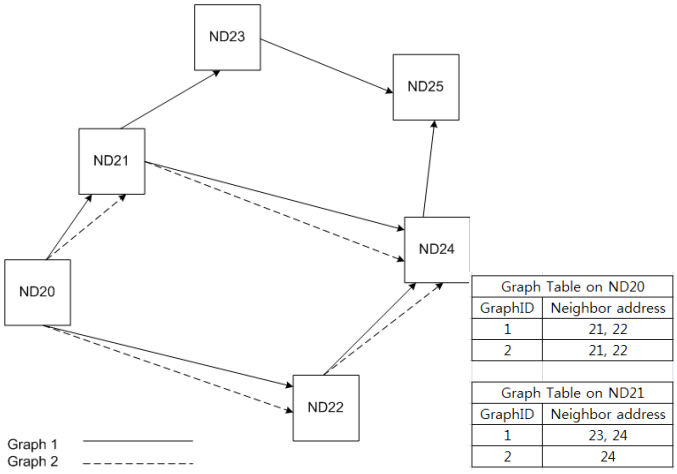
figure 1. Structure of Uncompressed DROUT Subnet header

However, the disadvantage that the size of a header is more bigger if the routing information is bigger and bigger in the source routing. The graph routing plays the role that it binds every node on one route (graph) with one ID and reduces the size of a header in order to overcome this disadvantage. In the every node, there exists the graph table which has next hop information of each graph ID for transmission. node

determine the next hop by comparing with graph table and packet header. The graph information and graph table are described and distributed by the system manage to the each node according to each graph. A policy and the method of drawing this graph were not determined by a standard and the self-regulated graph generation which it is stricken on each industry system is recommended.

octets	bits							
	7	6	5	4	3	2	1	0
1 octet	Compress=1	Priority (Unsigned4)				DlForwardLimit (Unsigned3)		
0-1 octet	DlForwardLimitExt (Unsigned8)							
1 octet	GraphID (Unsigned8)							

figure 2. Structure of Compressed DROUT Subnet header



Graph Table on ND20	
GraphID	Neighbor address
1	21, 22
2	21, 22

Graph Table on ND21	
GraphID	Neighbor address
1	23, 24
2	24

figure 3 Example of Graph routing and Graph tables

B. Shortest Path Graph - ELHFR algorithm

The Enhanced Least Hop First Routing (ELHFR) is one of the graph generation method sets the graph has minimum number of hop from a source to a destination. If a graph is set according to the network joining order, the graph detoured due to an inefficient can be generated. For prevent this problem, comprising all nodes through the Breath First Search Tree and using the Distance Vector method like AODV, and etc., the shortest route is found. Generally, in a network, moving through the shortest path means that arrive to the destination rapidly. In addition, the number of node required for transmission is decreased and the energy efficiency can be maximized. However, in the TDMA based network like ISA100.11a, it cannot refer to that the shortest graph arrives quickly in a destination because the determined time slot schedule exists. The node in which its own turn is already terminated have to wait next superframe duration for the electrical transmission. In addition, the energy efficiency is not good because the additional sleep awake phase has to be performed.

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III. TIME SLOT SCHEDULE BASED FAST GRAPH ROUTING

In ISA100.11a standard use TDMA based MAC protocol that is one superframe is divided several timeslots for reducing an interference and guaranteeing the reliability. When nodes join in the network, System Manager advertise the superframe structure and time slot schedule to each node through the provisioning process. A node repeats transmit/receive and active/Inactive phase as delivered its own schedule. This paper proposed the graph generation method consider about schedule of superframe time slot that communicate quickly from source to destination in ISA100.11a network. By this, The times per unit transmission Throughput is increased. The efficiency of the energy is raised by maximize guaranteeing the Sleep Phase.

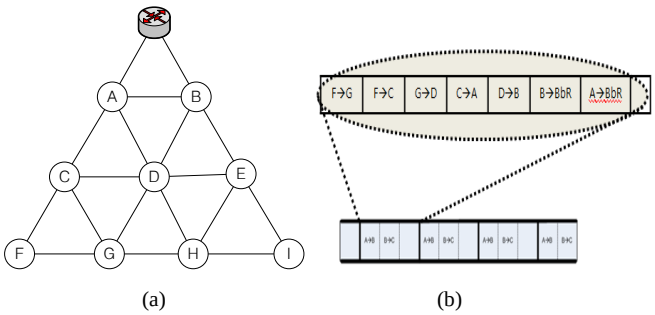


figure 4 Concept of Fastest Graph by Superfrme Time slot

In the topology like the above figure 4(a), the shortest graph from node F to the backbone router is the route with the F-C-A-BbR . However, in the superframe structure like figure 4(b), it is the more faster graph in which the route of F-G-D-B-BbR can reach rapidly to the backbone router.

A. Graph Generating

In the ISA100.11a standard, the time slot of a superframe is not assigned to the specific node. The time slot is assigned to the specific Directed Edge like the Node A to Node C. The System Manager gives the order of the time slot for each edge on the topology. At this time, all edges assume that an once is one time used for one superframe duration. In addition, considering the energy efficiency, we assume that there are no graphs have the number of hops over twice of shortest path graph. Figure 5 shows the time slot order of each link and the nodes which is in a route less than two times than length of the Shortest path till destination from source. The follow described technique is the simulation situation where it occurs in order to find the fastest graph in the System Manager where it is not physical transmission occurring actually between nodes. First, the system manager calculates required superframe duration number of transmission by shortest path graph. By the topology and schedule of figure 5, the shortest number of hop is 4 hops and the superframe duration of the total 3 number is needed. A source advertise the Graph Generate (GG) message to all neighbor nodes to scheduled all timeslots. The node who received GG message from the source tranmit the GG message to the its neighbor node in its own time slot if its own time slot order did not come around yet.

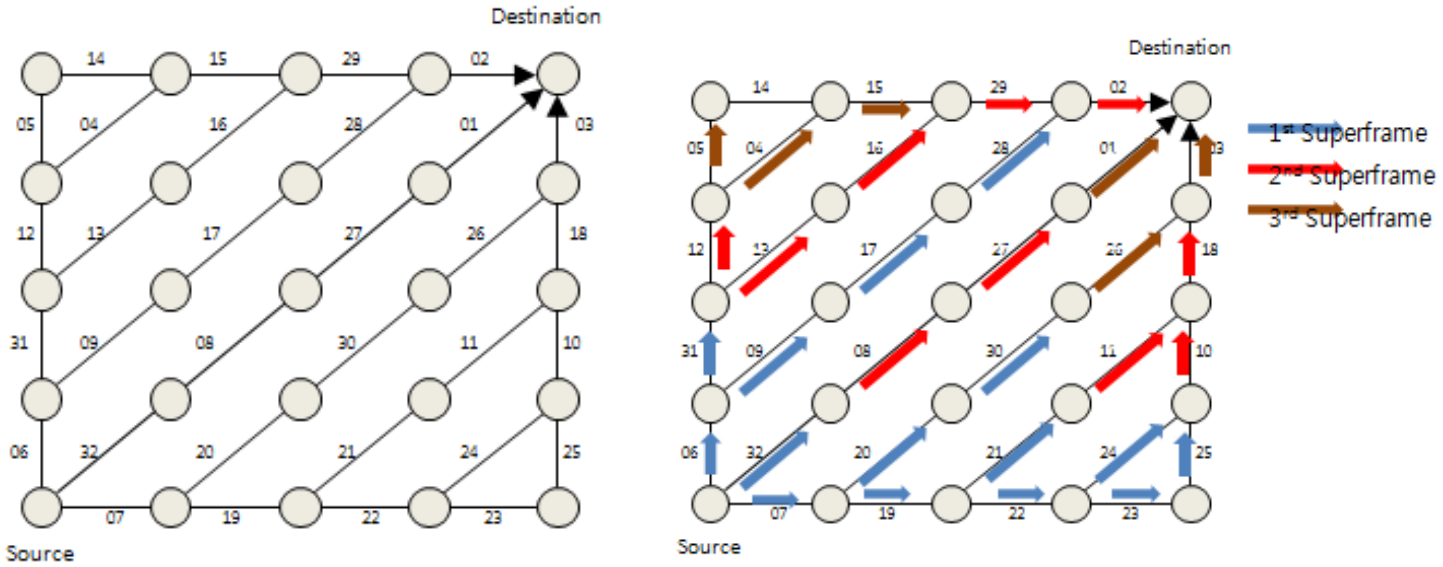


figure 5 GG Message Flow at each Superframe duration

The blue arrow of figure 5(b) shows the message flow of the first superframe. In figure 5 (b), the red arrow shows the packet transmitted in the second superframe. We can find that the fastest path exists reducing one superframe duration than the shortest path. If the faster path exists more than one, System Manager chose the least hop path graph. If we repeat above task pre-stored number that superframe duration of using shortest path graph times, we can fined more fast graph or that fact the shortest graph is same the fastest graph.

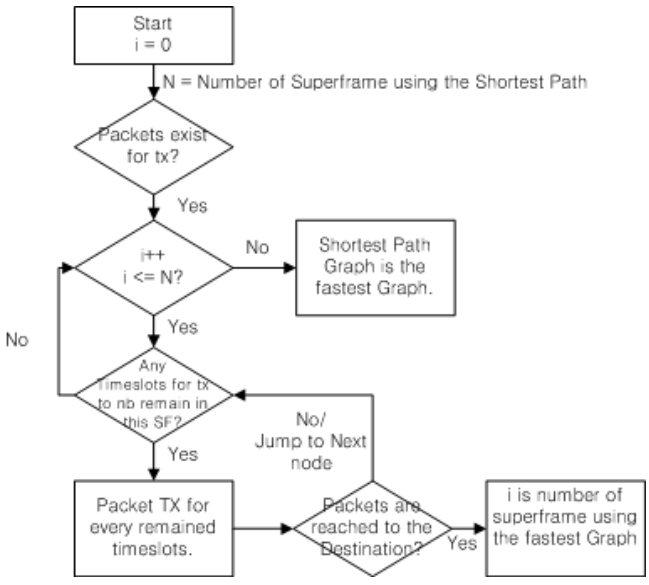
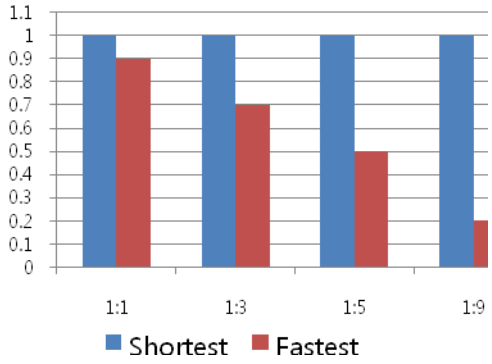


figure 6 Fast Graph Algorithm

IV. EVALUATION

An evaluation was progressed by using C/C++ language in Windows, the both ends of one diagonal of the N*N square topology was defined like figure 5 as a source and destination. Time slot order of each edge is set randomly inside one superframe. If the shortest graph and the fastest graph became the same graph, it excluded from the result of an experiment.

End to End Delay

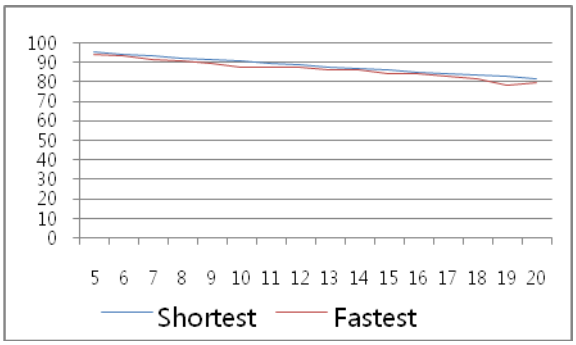


Graph 1 End-to-End Delay Comparison

In the graph 1, the rate of the End to End Delay according to a rate between Active:Sleep section is shown. When defining the End to End Delay of the Shortest Path graph as 1, as the rate of the inactive section is high, the high performance improvement is shown in the End to End Delay.

Reliablity

As the number of hop increased from the simple transmissions which doesn't consider the reliability mechanism (duo cast or Multipath Graph) of the graph routing of ISA100.11a, the reliability reduction seemed to be generated.



Graph 2 Reliability Comparison

Network error rate of fading or nature noise is defined 1%. Packets are delivered successfully by 99% chance during 1 hop transmission.

Throughput

In the UDP network, there are no deference between shortest path and fast graph. However, in the TCP network using congestion window, there are large gaps in this two mechanisms. Because end to end delay of fast graph is very little and it means that fast ack from destination and increasing congestion window size more quickly. At the result, throughput of fast graph is better than shortest path graph.

Energy efficiency

Need more evaluation about transmission/receive and awake/sleep phase.

V. CONCLUSION

This paper is the Fast graph routing method maximizing the transfer rate and minimize end-to-end delay of the graph routing used in the ISA100.11a standard. In the ISA100.11a network in which the time slot schedule is already determined by the System Manager. The superframe required for the electrical transmission produced the least graph. By maintaining as it is and minimizing the End to End delay the reliability can sense rapidly the urgent situation including the fire prevention of crime, and etc.

VI. ACKNOWLEDGMENT

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