Facility Networking with IP over RS485: Packet Control for Master-Slave Cascaded Networks

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***Abstract*—In Smart Grid applications, we need to access end devices for monitoring and control over varieties of communication media (e.g., wireless, wired and power-line communications). The Internet Protocol is useful because it can integrate those heterogeneous media by *IP over X* architecture. In this paper, we focus on the integration of RS485, an optimal communication media for facility networking in buildings, proposing *IP over RS485*. We introduce a dynamic priority-based packet-control scheduler (DPPCS) with master-slave and token-passing, and control the transmissions of IP packets on RS485. According to our evaluation with a 20-node and 200-meter scale RS485 testbed, IP over RS485 can perform well for many facility networking applications. It shared the bandwidth among active IP communication nodes. The buffering duration for non-active nodes to transmit the first IP packet were moderate. It had great tolerance for simultaneous packet transmissions.**

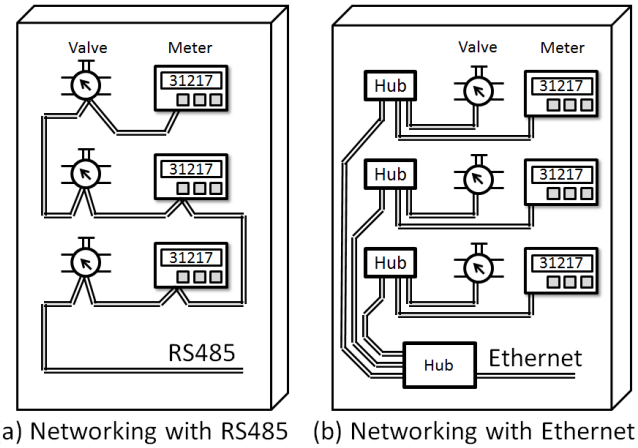
***Keywords*—Building Automation, IP, RS485, Facility Networking**

I. Introduction

Smart Grid requires a facility administrator to monitor power usage and to control HVAC (heating, ventilation and air-conditioning), lights, power outlets, and other facilities in buildings in near real-time. We are now trying to use the Internet Protocol (IP) to achieve this goal[7], [16]. IP is considered to be useful for providing basic connectivity to the interfaces of monitoring and control devices over heterogeneous communication media. For example, 6LoWPAN[13] has enabled to provide IP connectivity to such end devices over IEEE802.15.4 wireless links. However, legacy wired-networks especially used for monitoring and control applications still do not have IP-layer over it.

RS485 is one of the legacy communication media, which allows low-cost and reliable deployment of facility networks. It is commonly used in buildings worldwide almost as a de-facto standard. However, the implementation of IP-layer over RS485 is still not common, or even not sufficiently studied according to our survey.

This paper proposes the architecture of *IP over RS485*, which enables IP-based facility networking over the well-matured, low-cost and reliable communication media for buildings. We take master-slave and token-passing (MS/TP) scheme to control the delivery of IP packets over RS485. We introduce a dynamic priority-based packet-control scheduler (DPPCS) to optimize IP-based communication on RS485, and study the performance regarding to (1) packet buffering duration, (2) throughput and (3) tolerance for simultaneous packet transmissions.



(a) Networking with RS485 (b) Networking with Ethernet

Fig. 1. RS485 is one of the most optimal communication media for facility networking. If we use Ehernet, we have to deploy switching hubs and many UTP cables.

RS485 is a half-duplex, low-speed and multipoint serial communication media. It connects multiple nodes in cascaded manner usually on a single twisted-pair cable. It makes serial communication with differential signaling over 1km. The typical link speed for RS485-based networking is between 9.6kbps and 115.2kbps.

RS485 allows low-cost installation compared to the switch-based Ethernet (i.e., 10Base-T and above). It allows the installation with only a single cascaded cable from the master node to the monitoring and controlling devices (i.e., slaves). However, if we use Ethernet, we have to deploy UTP cables from the switching hubs to the devices one-by-one over the ceilings or behind the walls.

Typically, RS485 comes with an application protocol such as Modbus[12], BACnet[6] and Profibus[2]. They commonly take MS/TP schemes for delivering their application messages. We also take this approach for delivering IP packets over RS485. MS/TP avoids data-frame contention and provides the capability of traffic control, which is suitable for such a half-duplex and low-speed media.

DPPCS, which we introduce in this paper, schedules *tokens* that delivers IP packets. By watching the demand of IP communication of each node, it optimizes IP traffic (i.e., reduces latency and maximizes throughput) by appropriately and dynamically changing the schedule of tokens.

This paper provides our evaluation work carried out on

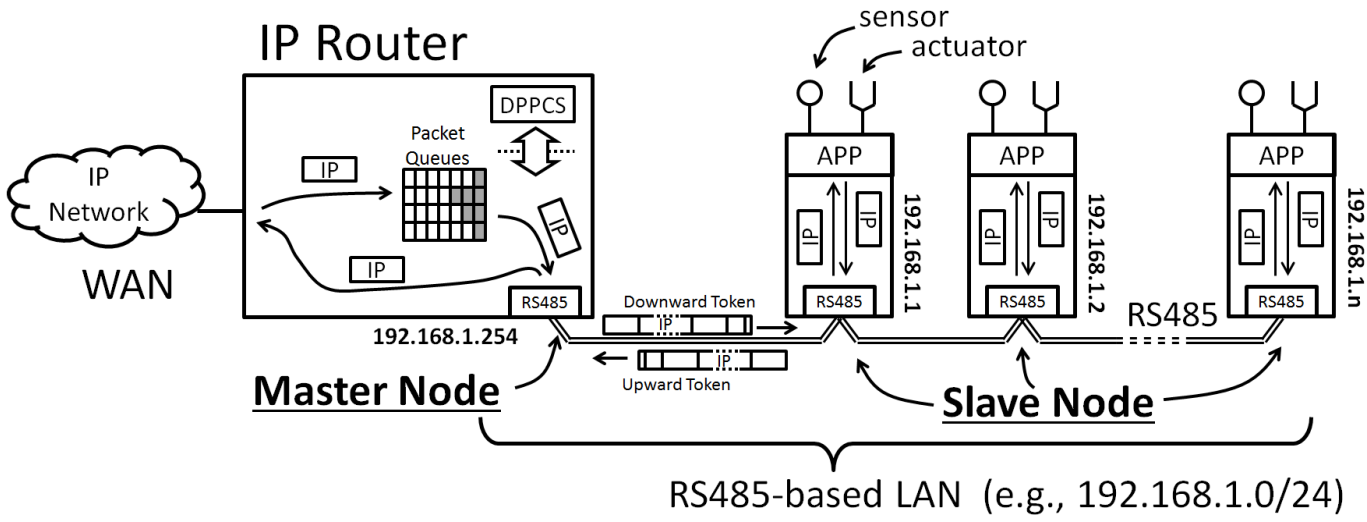


Fig. 2. IP over RS485 with Master-Slave Token-Passing. The master node sends downward tokens to slave nodes and receives upward tokens replied by slaves. They exchange IP packets along with tokens. The master node optimizes IP traffic on RS485 with dynamic priority-based packet control scheduler (DPPCS).

our RS485 testbed. The testbed has twenty RS485 slave nodes connected on a 200-meter twisted-pair cable. We implemented IP over RS485 and DPPCS, and evaluated (1) packet buffering duration at slave nodes, (2) throughput and (3) tolerance for simultaneous packet transmission. In facility networking, we sometimes collect sensor readings with, for example, 1 minute interval. The evaluation of the tolerance for simultaneous transmission is for such a case, where all the devices may send packets simultaneously.

This paper is organized as follows. Section II describes the architecture we target in this paper. Section III introduces DPPCS which we designed for the target network. Section IV shows our evaluation work. We provide discussion and related works in section V, and conclude this paper in section VI.

II. IP over RS485 with Master-Slave Token-Passing

Figure 2 shows the architecture of IP over RS485 with master-slave token-passing. The IP router in this figure has two interfaces for wide area network (WAN) and local area network (LAN). Here, the LAN is implemented on RS485 network. The LAN-side interface of the router works as a *master node* for the RS485 link. The devices connected to the link work as *slave nodes*. They have unique IDs to be addressed on the link. They also have IP addresses, and they can communicate with hosts over the IP network.

A. Token for IP packet delivery

We introduce *token*, which delivers an IP packet over RS485. A token is a small message exchanged between the master and one of the slaves on RS485. Figure 3 shows the data structure. It is organized with downward/upward (D/U) bit, slave ID, length of IP packet field, IP packet, and CRC checksum. If the D/U bit is 1, this token is for downward, which means from the master to the slave specified by the slave ID. If the D/U bit is 0, this token is for upward, meaning that it is going to the master from the slave specified by the slave ID. A token can carry one IP packet from the master to the slave or from the slave to the master. The length field tells the length of the IP packet, if this is 0, no packet is followed by. The data frame is closed with CRC checksum to detect the error which may occur during the transmission over RS485.

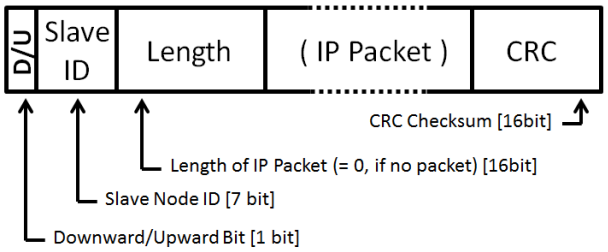


Fig. 3. Token frame format for IP packet delivery on RS485

B. Master Node

To control the delivery of IP packets on RS485 link, the master has a dynamic priority-based packet-control scheduler (DPPCS) and queues for outgoing IP packets. It sends a downward token to a slave specified by DPPCS, and receives an upward token replied by the slave. If there are packets for the slave in the outgoing queue, the master attaches the one to the downward token before sending. If the upward token contains a packet, the master receives this packet and passes it to the forwarder of the IP router.

To more formally describe, let s be an identifier of the slave node, that DPPCS has provided as the next target to access. Let Q be the set of the queues for outgoing IP packets. $q_s (\in Q)$ represents the outgoing queue that buffers the IP packets for s. We denote t_s^d a downward token to slave s, and t_s^u an upward token from slave s.

The master pops up a packet p from q_s. Then, the master generates a token t_s^d with attaching p and sends it over the

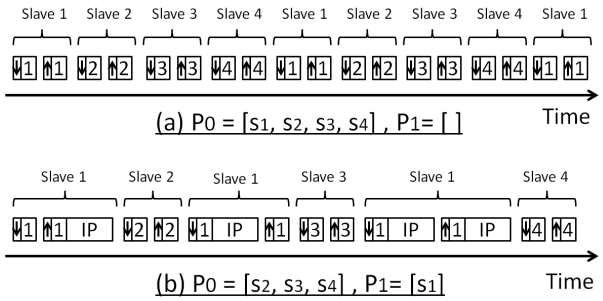


Fig. 4. Scheduling of tokens on RS485 by DPPCS. ↓ and ↑ means downward and upward tokens respectively. (a) When no packets are exchanged, DPPCS gets priority queues as $P_0 = [s_1, s_2, s_3, s_4]$ and $P_1 = []$. In this form, tokens are equally distributed to the slave nodes. (b) When only s_1 makes IP communication, DPPCS gets priority queues as $P_0 = [s_2, s_3, s_4]$ and $P_1 = [s_1]$. Then, token is passed to s_1 more frequently.

RS485 interface with turning it to transmission mode [1]. Here, if p is $null$ (i.e., no packet is contained in q_s), the master does not attach it to t_s^d, but sends it over RS485 nonetheless. After sending t_s^d, the master changes the interface to listen mode, and receives the token t_s^u responded by the slave. If t_s^u contains an IP packet, it posts the packet to the forwarder of the IP router.

Here, the master notify the information whether t_s^d and t_s^u contain IP packets or not to DPPCS for planning the schedule of tokens (see Section III).

C. Slave Node

We assume that a slave node has an application (APP) – a software instance, which manages sensors and actuators. A typical APP in facility networks, reports sensor readings to remote IP hosts, or receives actuator control signals from remote IP hosts. To exchange IP packets from such remote hosts, a slave has buffers for outgoing IP packets and incoming IP packets.

1) Outgoing Buffer Interfacing: When an APP wants to send an IP packet, it just puts the packet to the outgoing buffer. Then, when the slave replies an upward token t_s^u, it attaches the packet to t_s^u before sending. In this way, an IP packet sent by an APP goes to the IP router.

2) Incoming Buffer Interfacing: If a downward token t_s^d from the IP router contains an IP packet, the slave pushes the packet to the incoming buffer. An APP receives the packet from the incoming buffer. In this way, an IP packet delivered over the IP router goes to an APP.

III. Dynamic Priority-Based Packet-Control Scheduler

We introduce dynamic priority-based packet-control scheduler (DPPCS). DPPCS generates the next slave ID, which the master should pass a token to. DPPCS increases the throughput of IP communication by dynamically changing the form of providing tokens to the slaves which need communication.

[1]Please remind that RS485 is a half-duplex communication media. A node has to change the interface into transmission mode from listen mode when sending.

Algorithm 1: DPPCS Generation of the Next Slave ID

t: an integer that represents a virtual clock for this algorithm. initialized to 0 only at the first execution.
T_i: a constant integer that represents an interval on the virtual clock for providing a slave from P_i
$P_i.size()$: the size of P_i
$P_i.pop()$: pops up the queue.
$P_i.push(s)$: pushes s to the queue.
$skip_i$: a boolean variable initialized to *false* at the first execution.

```
1:  while true do
2:      foreach i ∈ {1, 0} do
3:          if P_i.size() > 0 ∧ t mod T_i = 0 ∧ ¬skip_i then
4:              skip_i := true
5:              s := P_i.pop()
6:              P_i.push(s)
7:              return s
8:          end if
9:      end foreach
10:
11:     t := t + 1
12:     foreach i ∈ {1, 0} do
13:         skip_i := false
14:     end foreach
15: end while
```

DPPCS defines two queues, which we denote by P_0 and P_1 in this paper. Both are the queues that contain slave IDs. 0 or 1 is intended for priority level. P_0 has the slaves to access with priority 0. P_1 has the slaves to access with priority 1, which means more frequent access. For example, if they are given as $P_0 = [s_2, s_3, s_4]$ and $P_1 = [s_1](s_i \in S)$, the master passes token to s_1 more frequently than s_2, s_3 and s_4 (see Figure 4). Here, S is the set of all the slaves available on RS485 link.

Whether s_i locates in P_0 or P_1 depends on the statistics of IP-layer communication on slave s_i. If any tokens $t_{s_i}^d$ or $t_{s_i}^u$ holds an IP packet, DPPCS takes s_i from P_0, puts s_i to P_1, and sets the validity time of s_i for P_1 to PRIORITY_TTL. PRIORITY_TTL is a constant value that how long, DPPCS should consider, the slave makes IP communication after the last IP packet exchange: e.g., 2 seconds. If there are no packet exchange with s_i for PRIORITY_TTL, DPPCS takes s_i from P_1 and puts s_i to P_0.

Algorithm 1 defines the DPPCS's generation of slave IDs. This algorithm is based on a virtual clock t, which increments until finding the next slave ID. P_0 and P_1 have their own interval of providing their slaves on the clock, which we define by T_0 and T_1. By setting $T_1 < T_0$, P_1 provides their slaves more frequently than P_0 does.

IV. Evaluation

This section provides our evaluation work on IP over RS485 with DPPCS. We have measured (1) buffering duration of IP packets at slave nodes, (2) throughput of IP traffic and (3) tolerance for simultaneous packet transmissions.

A. Experiment Setting

We have developed a testbed for IP over RS485 networking as Figure 5. This testbed is organized with 20 micro-controller boards (#1, #2, ..., #20), two IP routers, one host, and one log server. The boards have RS485 and Ethernet interfaces. We connected the RS485 interface to the testing network (i.e., RS485 network), and the Ethernet to the management network; we used this management network for collecting experiment logs. We have programmed our prototype slave node, and

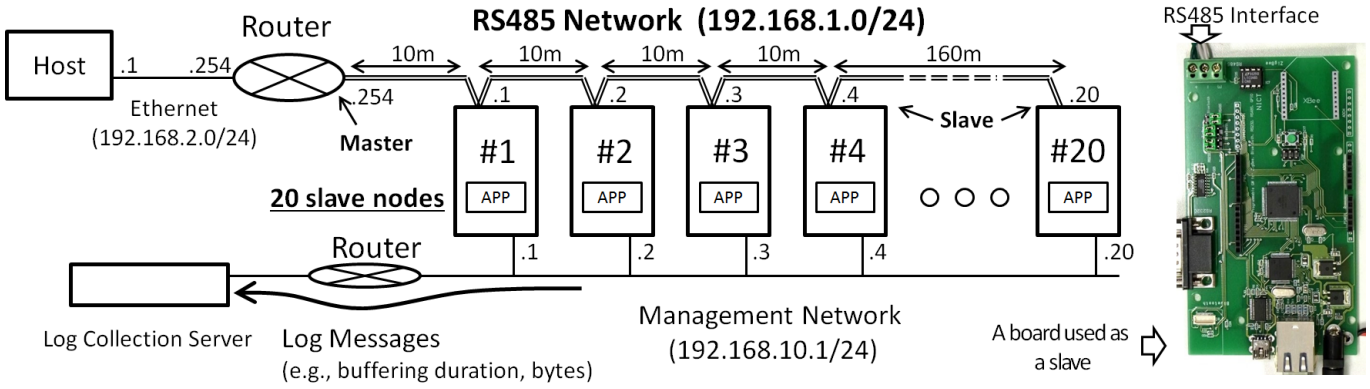


Fig. 5. IP over RS485 Testbed Configuration. We connected 20 micro-controller boards to RS485 network. We setup an IP router developed for our IP over RS485, installed application software on the host. The cable length from the router to slave #20 was 200 meters. The boards were also connected to the management network for collecting experiment logs.

TABLE I. HARDWARE CONFIGURATION OF THE EXPERIMENT

Node	Type	Description
Slave	Hardware	Arduino Mega 2560 Compatible
	RS485 Interface	LTC1485 Chipset
IP Router (Ethernet ↔RS485)	Hardware	Lenovo ThinkPad T60
	Operating System	Ubuntu Linux 12.04 server
	USB-RS232C Adapter	FTDI FT232RL Chipset
Host	Hardware	Lenovo ThinkPad X200s
	Operating System	Ubuntu Linux 12.04 server

installed it to the boards with assigning identifiers from #1 to #20 (so, all the 20 boards have worked as the slave nodes). We have also programmed our prototype master node on serial interface and on Linux TUN/TAP interface. We installed and executed it on a laptop, which had USB-RS232C serial adapter and RS232C-to-RS485 converter, using the laptop as an IP router. Please refer to Table I for the detailed configuration.

We connected each node with 10 meter twisted-pair cables in cascaded manner as the Figure 5. Thus, the total cable length from the master to slave #20 was 200 meters.

In the following experiment, we have configured the serial interface for RS485 with 115.2kbps, no parity and one stop bit. We have set PRIORITY_TTL=2000 [msec], T_0=100 and T_1=10.

B. IP Packet Buffering Duration

In our IP over RS485 network, buffering of IP packets is necessary to actually transmit them on RS485 link. As *buffering* makes some delay for the delivery of IP packets, we have evaluated the buffering duration of IP packets on our IP over RS485 network. In the experiment, we have focused on the time of sending packet from a slave node. We measured the duration between the time that an application on a slave node generates an IP packet, and the time just before the slave node sends the upward token which carries the packet.

In this experiment, we have setup two cases for the pattern of IP packet generation: (1) Long-Interval Case and (2) Short-Interval Case. In the long-interval case, the application has sent packets with 4 second interval, whereas in the short-interval case, 1 second interval. As the network works for 2 seconds for DPPCS priority control, we have expected that the packets in the long-interval case will not be prioritized, but the packets in the short-interval case will be prioritized. To evaluate the priority control scheme in more detail, we have also changed the number of active neighbor slaves. "active neighbor slaves" were the nodes which sent 32 byte packets every second, which were expected to be prioritized by the DPPCS.

The active neighbor slaves do not include the measurement node. We have used slave (#20) for the measurement of the buffering duration, and other nodes for active neighbor slaves. We used 64-byte long packet with more than 250 samples for the measurement.

Figure 6(a) shows the evaluation result of the average duration. When there were no active neighbor slaves, the average buffering duration for long and short-interval cases were 50.0[ms] and 2.58[ms] respectively. This was because, in the long-interval case, when the application generated an IP packet, DPPCS scheduled tokens to every node equally, but in the short-interval case, it scheduled most of the tokens to the measurement node.

When there were one active neighbor slave, the average duration changed to 429[ms] and 5.06[ms]. This was because, in the long-interval case, DPPCS scheduled most of the tokens to the active slave and less token to the measurement node. In the short-interval case, tokens scheduled by DPPCS were balanced with the active neighbor slave and the measurement node.

As the number of active neighbor slaves increased, the average buffering duration of the long-interval case decreased, this was because the number of slaves managed by priority queue 0 was decreased, and it got more chance to be scheduled in turn. The average buffering duration of the short-interval case increased, and when almost all the nodes were active, the buffering duration for long-interval and short-interval became almost the same.

Figure 6(b, c) show the buffering duration for each IP packet. These graphs show how the standard variations of the durations (drew as error bars in Figure 6(a)) are large.

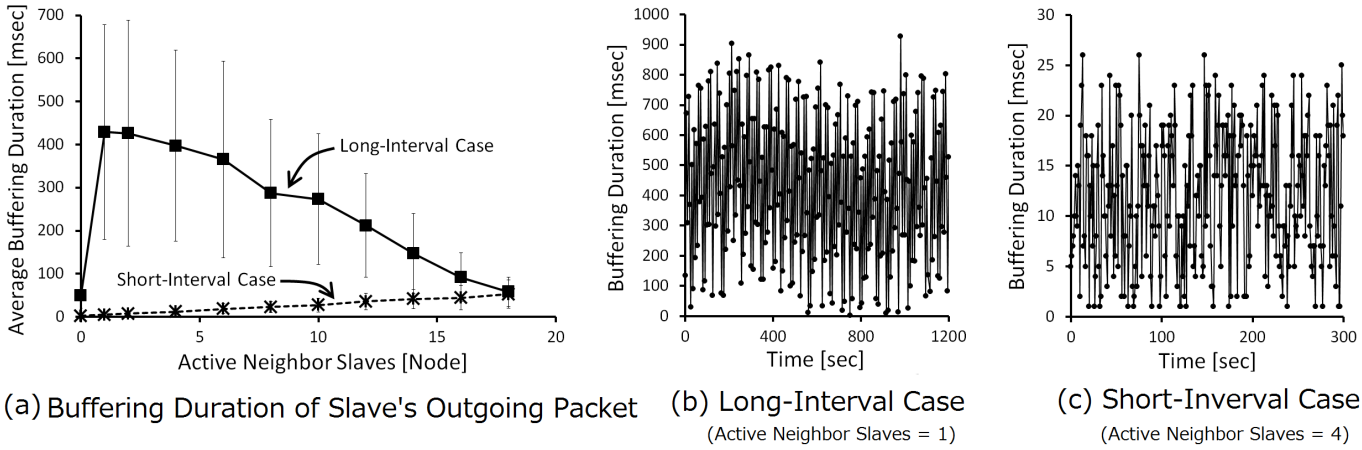


Fig. 6. Buffering duration of IP packets at slave's outgoing queue. (a) Average duration in long-interval and short-interval cases to the number of active neighbors. The error bar shows the standard variation of individual packet buffering duration. (b) Individual packet buffering duration in long-interval case. (c) Individual packet buffering duration in short-interval case.

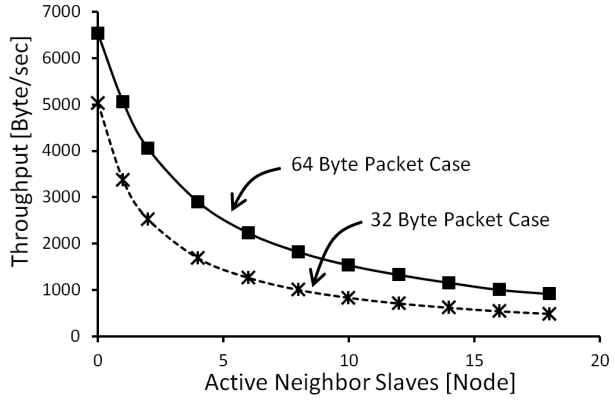


Fig. 7. Throughput of IP traffic from #20 to the Host. DPPCS scheduled tokens so as to share the bandwidth among active nodes.

C. Throughput of IP Traffic

Next, we have evaluated the throughput of IP traffic from slave #20 to the host. In this experiment, we have programmed an application that aggressively sends IP packets to the host. This application immediately generated a packet when the sending buffer was ready to store it. We have setup two cases for traffic measurement: 32 byte packet case and 64 byte packet case. For both cases, we measured the traffic that slave #20 had sent for more than 3 minutes. We also changed the number of active neighbor slaves, which sent 32-byte packet every second, to see how DPPCS's algorithm shared the bandwidth when the network had several active nodes.

Figure 7 shows the result. With no active neighbor slaves, the node achieved the best performance for both cases. For example, in the 64 byte case, it has achieved 6532 byte per second. As we use 115.2kbps with 1 start bit and 1 stop bit on RS485 link, this throughput corresponds to 56% use of the RS485's capacity. As RS485 is a half-duplex media and the link-layer has overheads for token exchanges, this result indicates that DPPCS is adequately controlling tokens so as to maximize the bandwidth for active nodes.

As the number of active neighbors increased, the throughput of the IP traffic decreased. This result indicates that the DPPCS has shared RS485 resource to other active nodes as we intended.

D. Tolerance for Simultaneous Packet Transmission

Finally, we have evaluated the loss and latency of packet delivery in simultaneous communication case. To carry out this experiment, we have implemented the following application instances on slave nodes (192.168.1.{1-20}) and the host (192.168.2.1). Each slave has sent an UDP datagram (i.e., IP packet) every 5 second simultaneously with other slaves to the host, and the host logged the received datagram with its timestamp. Each datagram has contained sender's slave node ID, and the serial number of the datagram, which increments every time the slave sends it. To synchronize the applications on slaves to generate datagrams simultaneously, we have modified the master to insert a small (= 5 octet) broadcast token on RS485 every 5 second. All the applications on the slaves have received this token, and then they have composed and sent UDP datagrams to the host at the same time.

We have carried out this experiment for about 70 hours from 2014-04-18 16:30. The length of the each IP packet exchanged in this experiment was 64 byte.

There was no packet loss during the experiment. Totally, the application instance of the host received 1,008,000 UDP datagrams from the slaves during the experiment. We have checked the slave IDs and the serial number of the messages, and found that the host received 50,400 datagrams from each slave without any loss (i.e., 100% delivery).

Using the log, we developed the distribution of delivery rate on latency-axis for receiving 5, 10, 15 and 20 datagrams after the first datagram arrival (see Figure 8). This result shows that it has achieved the delivery of 20 datagrams sent simultaneously from the slaves to the host within 1.2 seconds, which is acceptable in many monitoring applications.

These results indicate that our IP over RS485 network has a great tolerance for simultaneous packet transmissions.

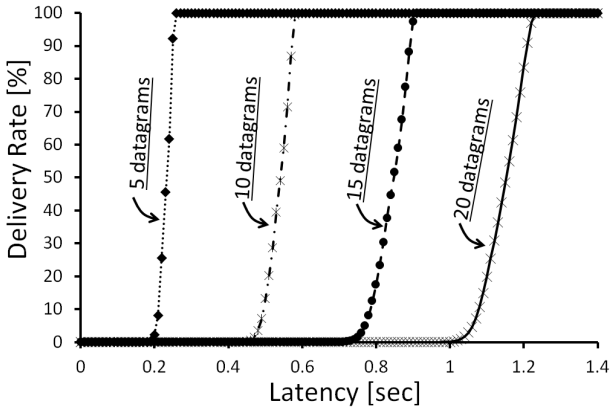


Fig. 8. Delivery rate vs. latency for delivering 5, 10, 15 and 20 datagrams sent simultaneously. Packets from all the slaves were delivered within 1.2 seconds.

V. Discussion and Related Work

The Internet protocol (IP) is considered to be a key technology for implementing a Smart Grid [7], [16]. Smart Grid is being built on the IP infrastructure – for collecting metering values [14], [17] and for controlling building facilities and houses [5], [15], [1]. There are many kinds of communication media possible to use here depending on the target field of deployment: e.g., Ethernet, GPRS, power-line communication (PLC), IEEE802.15.4 and RS485. IP achieves interoperability integration of those different communication media, which is necessary in the development of Smart Grid.

RS485 is known as a well-matured, low-cost and reliable wired communication media for monitoring and controlling facilities in buildings. Hui-juan et. al. [10] studied the implementation of RS485 over UDP in order to access remote RS485 device. Yongpan et. al. [17] developed a prototype building energy management system using RS485 devices over the Internet. Those works integrates RS485 devices on the Internet protocol but they do not deliver IP packets to end devices. As for IP over RS485, which delivers IP packets over RS485 line, according to [4], [3], Internet-0 project [9], [8] has studied IP over RS485 though the detail is not provided in the literature. In IETF's 6man working group, Lynn et. al. [11] drafted transmission of IPv6 over MS/TP networks intended to "IPv6 over RS485", but this internet-draft is expired and there seems no evaluation work.

In this paper, we have identified the possibility of IP over RS485 architecture, proposing a dynamic priority-based packet-control scheduler (DPPCS). We implemented the architecture, carried out experiments using our RS485 testbed, and demonstrated that it shared the RS485 resource among active nodes reducing latency and increasing the throughput as we intended. We also showed its great tolerance for simultaneous packet transmissions.

VI. Conclusion

We proposed and studied *IP over RS485* intended to enable IP-based facility networking over RS485. With master-slave and token passing scheme, we introduced a dynamic priority-based packet-control scheduler (DPPCS) that provide RS485 resources to the nodes which need IP communications.

We carried out evaluation on our RS485 testbed, organized with 20 slave nodes over 200 meter cable. With baudrate 115.2kbps, our prototype system (1) diminished the duration of IP packet buffering at slave node to 2.58[ms], (2) maximized the throughput to 6532 byte per sec, (3) achieved no packet loss over 70-hour experiment in a simultaneous transmission case (20 nodes and 5 second interval). DPPCS balanced the traffic among active communication nodes, with providing moderate latency for getting-active nodes.

References

[1] B. Adebisi, A. Treytl, A. Haidine, A. Portnoy, R. U. Shan, D. Lund, H. Pille, and B. Honary. Ip-centric high rate narrowband plc for smart grid applications. *Communications Magazine, IEEE*, 49(12):46–54, 2011.

[2] K. Bender. *Profibus: the fieldbus for industrial automation*. Prentice-Hall, Inc., 1993.

[3] N. W. Bergmann and P. J. Robinson. Server-based internet of things architecture. In *Consumer Communications and Networking Conference (CCNC), 2012 IEEE*, pages 360–361. IEEE, 2012.

[4] N. W. Bergmann, M. Wallace, and E. Calia. Low cost prototyping system for sensor networks. In *Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), 2010 Sixth International Conference on*, pages 19–24. IEEE, 2010.

[5] H. Broberg et al. Internet-based monitoring and controls for hvac applications. *Industry Applications Magazine, IEEE*, 8(1):49–54, 2002.

[6] S. T. Bushby. Bacnet: a standard communication infrastructure for intelligent buildings. *Automation in Construction*, 6(5):529–540, 1997.

[7] X. Fang, S. Misra, G. Xue, and D. Yang. Smart grid - the new and improved power grid: a survey. *Communications Surveys & Tutorials, IEEE*, 14(4):944–980, 2012.

[8] N. Gershenfeld and D. Cohen. Internet 0: Interdevice internetworking-end-to-end modulation for embedded networks. *Circuits and Devices Magazine, IEEE*, 22(5):48–55, 2006.

[9] N. Gershenfeld, R. Krikorian, and D. Cohen. The internet of things. *Scientific American*, 291(4):76, 2004.

[10] J. Hui-Juan and G. Zheng-hui. Research on the technology of rs485 over ethernet. In *E-Product E-Service and E-Entertainment (ICEEE), 2010 International Conference on*, pages 1–3. IEEE, 2010.

[11] K. Lynn, J. Martocci, C. Neilson, and S. Donaldson. Transmission of ipv6 over ms/tp networks, 2012.

[12] I. Modbus. Modbus application protocol specification v1. 1a. *North Grafton, Massachusetts (www. modbus. org/specs. php)*, 2004.

[13] G. Mulligan. The 6lowpan architecture. In *Proceedings of the 4th workshop on Embedded networked sensors*, pages 78–82. ACM, 2007.

[14] J. Wang and V. C. Leung. A survey of technical requirements and consumer application standards for ip-based smart grid ami network. In *Information Networking (ICOIN), 2011 International Conference on*, pages 114–119. IEEE, 2011.

[15] C. Warmer, K. Kok, S. Karnouskos, A. Weidlich, D. Nestle, P. Selzam, J. Ringelstein, A. Dimeas, and S. Drenkard. Web services for integration of smart houses in the smart grid. *Grid-Interop-The road to an interoperable grid, Denver, Colorado, USA*, pages 17–19, 2009.

[16] Y. Yan, Y. Qian, H. Sharif, and D. Tipper. A survey on smart grid communication infrastructures: Motivations, requirements and challenges. *Communications Surveys & Tutorials, IEEE*, 15(1):5–20, 2013.

[17] C. Yongpan, M. Xianmin, Z. Jili, and L. Zhen. Development of monitoring system of building energy consumption. In *Computer Science-Technology and Applications, 2009. IFCSTA'09. International Forum on*, volume 2, pages 363–366. IEEE, 2009.