A Wireless Backhaul Prototype with Capability of Over 10 Hops Relay

PicoCellular Extending Local access Area!

Contents

EXECUTIVE SUMMARY

This paper introduces a new Wireless LAN (W-LAN) system with wireless multihop backhaul. The system has been developed by MIMO-MESH project lead by Mobile Communication Systems Laboratory in Kyushu University to pursue a key infrastructure for next generation mobile communication system. With the developed system, W-LAN area can be added easily and arbitrarily without any cables, which can reduce costly cable constructions typically required for conventional W-LAN APs. No complex configurations are necessary in the proposed system: place a node, turn it on and then new W-LAN area gets ready.

A Wireless Backhaul Prototype with Capability of Over 10 Hops Relay

I. INTRODUCTION

Wireless communication is indispensable to our everyday social life. Many internet services that have been evolved in wired world are shifted onto wireless realm. The trend is accelerated with rapid penetration of modern personal devices such as Microsoft's Windows Mobile, RIM's blackberry, Apples's iPhone, Google's Android and so on. Fast penetration of them increases communication traffic, which gives much pressure on the wireless bandwidth being available today. In fact, some 3G operators offload traffic caused by iPhone to public W-LAN networks in order to mitigate traffic congestion of their 3G system.

According to many statistics reports, 70%~80% of broadband wireless traffic happens in indoor environment. So, it naturally concludes that priority should be put on brushing up indoor networks rather than outdoor ones. Giving priority to extend indoor coverage is surely appropriate too because outdoor coverage has been already maintained by 3G and some later standards even whose transmission speed is still lower than that offered by W-LAN.

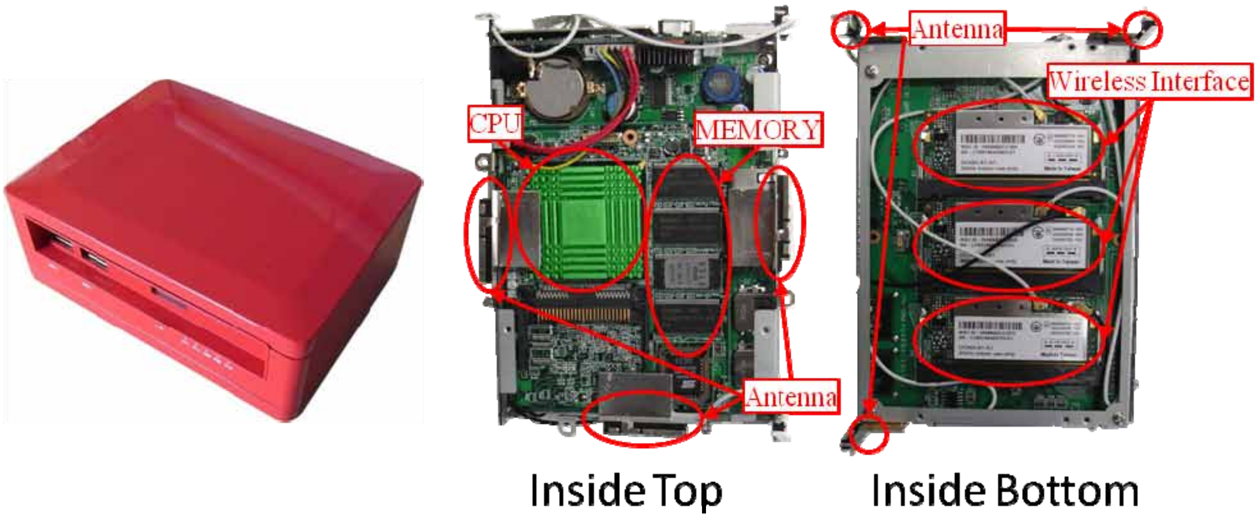

Fig.1 Outside and inside appearance of PicoMESH

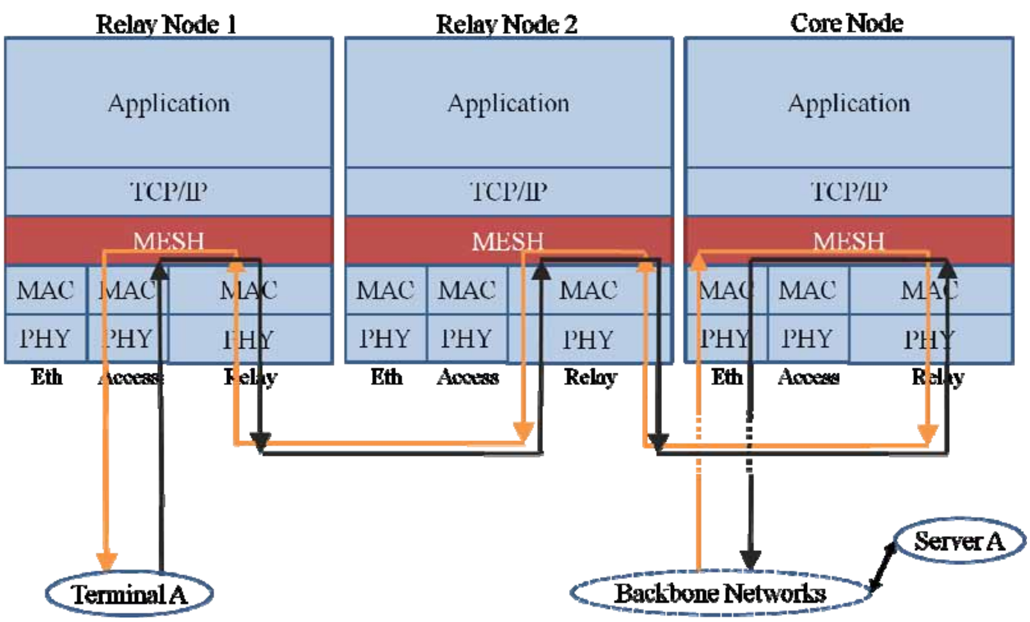

Fig.2 Protocol stack

Area gap is always a headache for system integrators who have responsibility to setup a broadband wireless communication system because planning of access point (AP) is not so easy. Radio propagation is hardly predictable in indoor situation due to its sensitiveness to obstructions such as walls, ceilings and furniture. In order to reduce AP deployment cost, many efforts has been made to establish an on-desk pre-design method of AP locations, however most of them fail to make us satisfied. More promising way of designing AP location would be an old heuristic fashion such that set and removal of APs are repeated until reaching a best possible formation. Problem is how to reduce cost of AP deployment employing such a brute force method.

Mobile Communication Systems Laboratory (MCSL) in Kyushu University is studying next generation mobile communication systems. Objective of the study is to pursue a key infrastructure of broadband wireless communication system enabled by intelligent backhaul with wireless multihop capability. Wireless backhaul is a wireless network among APs, which can remove costly cable constructions wired to APs to access internet. By making APs free from wired connections, addition, removal and move of APs are easily done. For the past few years, a great effort has been made on establishment of wireless backhaul system for outdoor solutions [1-3]. However, as aforementioned, since almost broadband traffic happens in indoor, those efforts fail to meet traffic demand.

MIMO-MESH project is a flagship project in MCSL supported by Ministry of Education, Culture, Sports, Science and Technology(MEXT), Japan and Fukuoka IST where we are developing APs with wireless multihop backhaul called PicoMESH. We focus on applying PicoMESH to indoor area extension. This paper introduces details of PicoMESH.

II. PICOMESH

A. Overview

PicoMESH is a battery drive, palm sized wireless LAN (W-LAN) AP with wireless multihop backhaul. Figure 1 shows outside and inside appearances of PicoMESH. Three wireless modules are built-in into PicoMESH so that it offers two simultaneous wireless relay links. The other single wireless module is used for providing W-LAN access network. PicoMESH can realize a highly expansive backhaul by allowing more than 10hop wireless relays. All hardware components inside are commodities which are originally used to build PCs. This feature will allow us to quickly rollout commercial version of PicoMESH.

Area setup is carried out as follows.

(1) Place one unit of PicoMESH and connect it to internet by cable. This special unit is called as core node because it serves as a gateway to internet. All PicoMESH units including core nodes can provide normal AP function, i.e. under coverage of the nodes, users can get online through IEEE802.11 based wireless NIC.

(2) Add another one unit of PicoMESH (the unit is called as slave node) in a place around where you want to expand W-LAN area. Any wire connections are not required at all for this newly added node. No deep consideration of the node's position is required because the unit can be easily moved to another place afterwards if you don't like the position. Core and slave nodes are made by the same hardware units and they share the same software as well. Each unit is set to either core mode or slave mode by simply turn a switch.

(3) Push on the "reroute" button of the newly added slave node. This action triggers a route establishment procedure for a given PicoMESH units.

(4) Wait for LED light of the newly added slave node. If turned on the light, a route from the slave node to the core node is surely established. If not so, the newly added slave node fails to establish a route. So change position of the node and return to the step (3).

(5) Repeat the steps through (2) to (4) until W-LAN area fulfills user's demand.

Major specifications of PicoMESH are summarized in Table I.

Table I Specifications of PicoMESH

CPU	AMD Geode LX800
MEMORY	DDR 512MB
Drive	1GB CF drive
Wireless Interface	3 x IEEE802.11a/b/g (one for access network and the other two for relay network)
OS	Linux Kernel 2.6
Battery life	5H
Weight	990g including battery
Interfaces	USB X 2, Ethernet X 1

B. Backhaul Engine

A heart of PicoMESH is its unique driver software that handles wireless multihop relays. Figure 2 shows protocol stack of PicoMESH's backhaul engine. All the functions for mutihop relaying are run on L2.5 whereby any services that work in L3 and above layers requires no additional designs for their adoption to PicoMESH network. An IP address issued to a mobile device is held when the device moves to another cell. This means that PicoMESH offers handover. Handover is carried out in L2 level and all necessary processes for the handover are maintained by PicoMESH's L2.5 backhaul engine so that system integrators are free from difficult system design issues.

III. KEY TECHNOLOGIES

In this section, two key technologies behind PicoMESH are introduced. It should be noted that the technologies occupy essential part of the system but they are not only ones that keep the system alive.

A. Statistical Mesh Routing

Even though the product name of PicoMESH includes the word "mesh", it does not mean that we rely on typical mesh network. Any routes connecting any two of nodes are unique in PicoMESH's route but not unique for the typical mesh route assumed here. PicoMESH adopts tree topology route in which core node is in charge of root in a tree. Tree is periodically updated and it can change depending on radio condition at respective updates. Under such a situation, if we take cumulative route for a long period of observation time, resultant route after the statistics looks like a mesh. So we call this routing as statistical mesh routing. Figure 3 shows graphical representation of the statistical mesh route and typical mesh route in the same node layout.

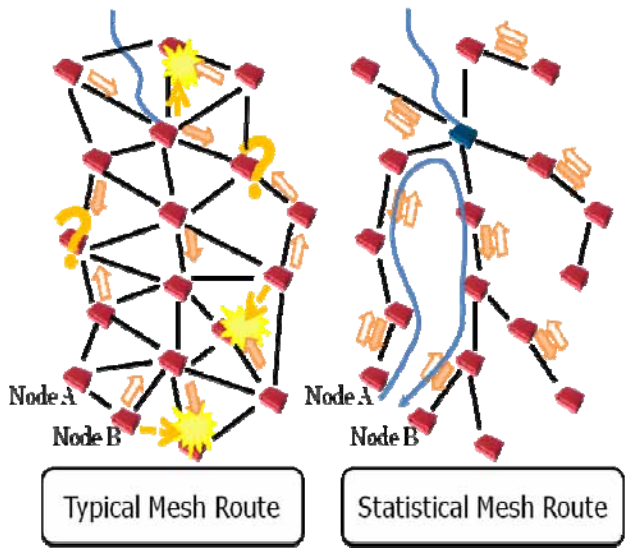

Fig. 3 Statistical mesh route and typical mesh route

With the statistical mesh route, the number of intersections on forwarding path is fewer that that happens in the typical mesh route as found from Fig. 3. The statistical mesh route needs a simpler scheduling algorithm than that required for the typical mesh route. Let's suppose a case when node A forwards a packet to node B in Fig. 3. With the typical mesh route, the packet can be forwarded to node B for a short time period due to single hop relay. However, this is the case if no packets are exchanged among the surrounding nodes. A complex packet scheduler is necessary for the typical mesh routing because many packets with different forwarding path fly across the intersections. In order to prevent collisions, the scheduler has to repeat stop and wait of packet forwarding, which reduces packet forwarding efficiency. On the other hand, with the statistical mesh routing, the packet is forwarded from node A to node B in 8 hops period. Such a large hop relay also looses packet forwarding efficiency, however, the scheduling loss that has to happen in the typical mesh route is mitigated because tree topology contains fewer intersections than typical mesh topology.

B. IPT forwarding

In order to enable the statistical mesh routing, a large number of hops have to be handled. This objective is not tractable due to radio interference. The most unique feature which discriminates PicoMESH from the other testbeds is its packet forwarding scheme. Intermittent Periodic Transmit (IPT) forwarding is a powerful packet forwarding scheme which can effectively mitigate interference on a forwarding path in large hop counts scene [4] [5].

Figure 4 shows packet forwarding flows for a conventional forwarding and IPT forwarding. With a conventional forwarding, source packets are forwarded to the next hop node without any waiting period. The outgoing packets sent from the source node (also from an intermediate node) sometimes interfere with other outgoing packets from other nodes as shown in left hand flow of Fig. 4, which deteriorates forwarding efficiency.

With IPT forwarding (shown in right hand flow in Fig. 4), packets originated by a source node are intermittently sent to a destination node with an intentional transmit period and each intermediate node forwards packets immediately upon reception of forwarded packet from the previous hop node. Though someone may wonder if such an intentional period setting reduces transmission efficiency, this is completely misinterpretation.

As found from the left side flow of Fig. 4, once a node fails to forward a packet, it tries to send it again after taking random backoff period. Such multiple trials for the same packet reduce forwarding efficiency much. When looking at IPT, the longer the transmit period, the longer is the reuse space which is defined as separation between adjacent co-transmission node. If a minimum transmit period is set on the source node, reuse space can be also minimized, which results in maximized packet forwarding efficiency.

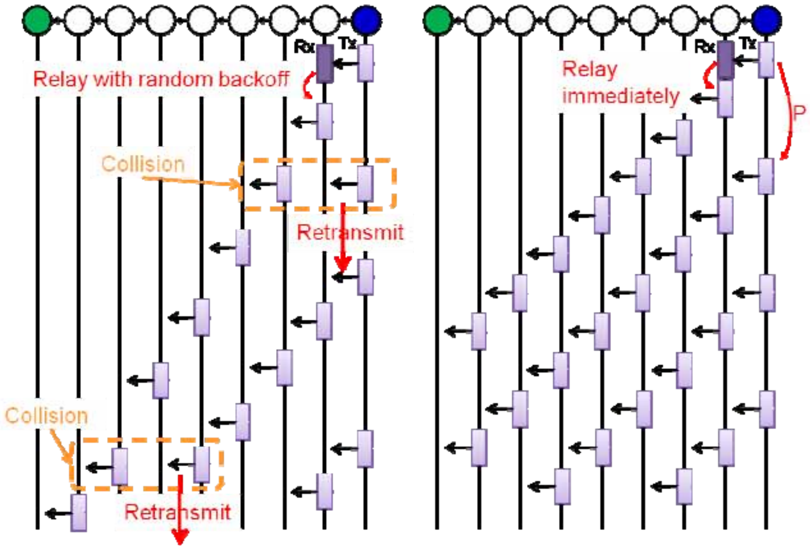

Fig.4 Packet forwarding flow for a conventional forwarding and IPT forwarding

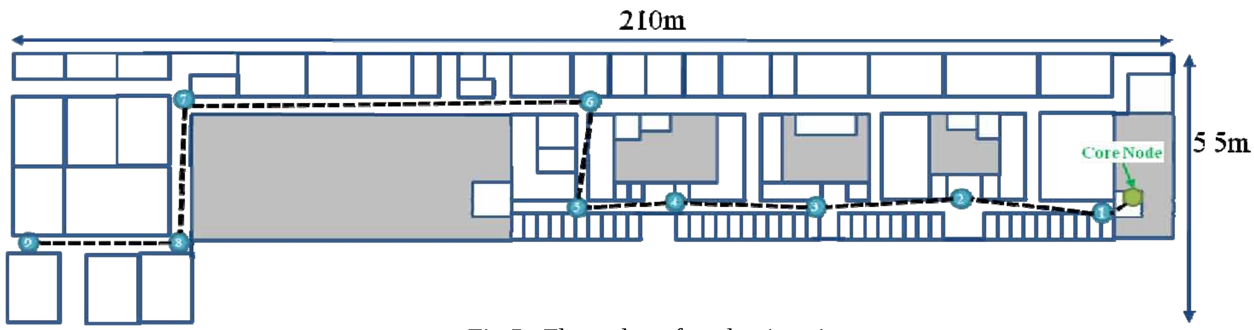

Fig.5 Floor plan of evaluation site

IV. PERFORMANCE OF PICOMESH

This section exhibits throughput and delay performances achieved by PicoMESH.

A. *Evaluation condition*

Evaluation site is our department building located in Ito campus. Floor plan is shown in Fig. 5. We setup 10 units of PicoMESH distributed over 200m x 5.5m area as shown in Fig.4. Relay wireless modules run in 36Mbps bearer mode each. Throughput measurements were done by iperf tool [6]. UDP packets with MTU size of 1470byte and constant bit rate (CBR) traffic are assumed. Transmit power is set to 17dBm for each relay wireless module.

B. *Throughput performance*

Figure 6 shows throughput versus hop count for cases with IPT and without IPT. As found from Fig. 6, IPT shows improved throughput performances. For 9 hop count case, IPT achieves double throughput compared with the case without IPT.

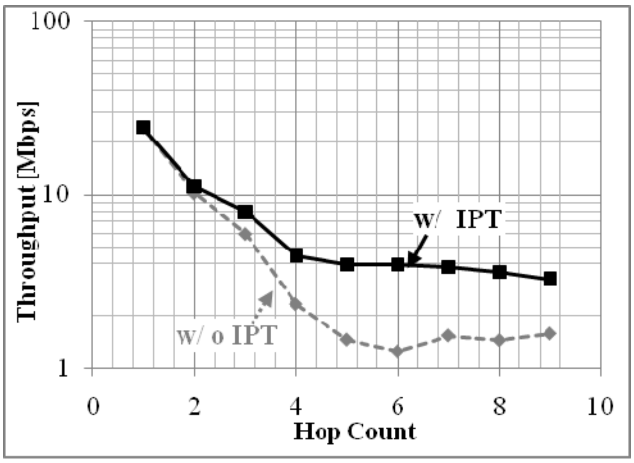

Fig. 6 Throughput versus hop count

C. *Handover delay*

One of the important features of PicoMESH is its capability of L2 handover. This section exhibits handover delays measured in real system.

When a mobile terminal moves into a different cell, it at first tries to associate with the node covering this new cell. After the association, a new forwarding route from the associated node to the core node is found.

According to detailed assessments of handover process, average association delay and average route establishment delay were detected to 6.33sec and 0.19sec, respectively. Association delay completely depends on an AP switching software installed to mobile terminal but no responsibility to PicoMESH. In this sense, we should conclude that handover delay due to PicoMESH is 0.19 sec. This level of handover delay is short enough if compared with current cellular phone systems.

V. CONCLUTION

This paper introduces PicoMESH, a W-LAN system with wireless backhaul capability. From experimental evaluation results, PicoMESH achieved higher throughput and shorter handover delay compared with counterpart technologies. In order to commercialize the technologies gained through studies over PicoMESH development, a company named PicoCELA Inc. has been launched. Product version of PicoMESH is now available.

REFERENCES

[1] A. Capone, S. Napoli and A. Pollastro, ”MobiMESH: An Experimental Platform for Wireless MESH Networks with Mobility Support,” Proc. of ACM QShine 2006 (WiMESHNets 2006, Workshop on "Wireless mesh: moving towards applications"), Waterloo (Canada), August 10, 2006

[2] E. C. Haddad and J.-C. Gregoire, “Implementation issues for the deployment of a WMN with a hybrid fixed/cellular backhaul network in emergency situations”. Proc. 1st International Conference on Wireless VITAE 2009, pp. 525 – 529, May 2009.

[3] S. L. Shrestha, J. Lee, A. Lee, K. Lee, J. Lee and S. Chong. ” An Open Wireless Mesh Testbed Architecture with Data Collection and Software Distribution Platform,” Proc. 3rd International Conference on Testbeds and Research Infrastructures for the Development of Networks and Communities (TridentCom), May 2007.

[4] H. Furukawa. ”Hop Count Independent Throughput Realization by a New Wireless Multihop Relay”. VTC04_fall, pp. 2999-3003, 9 2004.

[5] H. Furukawa, Y. Higa, R.-G. Cheng and J.-S. Yang, “Proposed text for frame forwarding on 802.11s”, IEEE802.11-05/770r0, June 2005.

[6] E. Yildirim, I.H.Suslu and T. Kosar, “Which network measurement tool is right for you? a multidimensional comparison study,” Proc. IEEE/ACM International Conference on Grid Computing 2009, pp. 266-275, Sep. 2009.

Hiroshi Furukawa

Department of Advanced Information Technology,
Kyushu University
Fukuoka, Japan
furuhiro@ait.kyushu-u.ac.jp

PicoCELA Inc.
6F Onuki Hakataekimae Bldg.,
3-6-12 Hakataekimae, Hakata-ku,
Fukuoka-city, 812-0011, Japan
Phone: +81 92 474 3800 FAX: +81 92 483 5727
URL: http://picocela.com/en/
E-mail: info@picocela.com

PicoCellular Extending Local access Area!