Heterogeneous Mesh Router with Mesh Connectivity Layer on IXP425

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Abstract

In this paper, we propose an efficient design of a heterogeneous mesh router, using network processors. Wireless Mesh Network (WMN) is a multi-hop wireless network, comprising two kinds of nodes-mesh routers and mesh clients. Microsoft Research has developed Mesh Connectivity Layer (MCL) for computers that use Windows operating systems. In MCL routing is done using a protocol called Link Quality Source Routing (LQSR), which is a Microsoft adaptation of the Dynamic Source Routing (DSR) protocol. LQSR is optimized for mesh scenarios. We propose an efficient method to increase the performance of the overall network by extending the MCL to network processors (IXP425) and making the network processors act as routers/gateways, connecting heterogeneous networks. The network processor with its inherent support for network processing tasks helps in realizing a significant improvement in the performance of the network.

Keywords: IXP425 Network Processor, Mesh Connectivity Layer, Bluetooth, 802.11 WLAN, Wireless Mesh Network, Link Quality Source Routing, Heterogeneous Network.

1. Introduction

Wireless Mesh Networks have been an important area of research for the past few years. Several applications like broadband home networking, community and neighborhood networking, enterprise networking, metropolitan area networks, transportation systems, health and medical systems, security surveillance systems, etc., which cannot be directly supported by other wireless networks like cellular networks, ad-hoc networks, wireless sensor networks, standard 802.11, etc., are driving research and development of WMNs [4]. MCL is a loadable Microsoft Windows Driver [1]. It is developed for machines using general-purpose processors running Windows XP. This restriction limits the performance of the network considerably. We propose to overcome this limitation by realizing MCL on IXP425, which has been specifically designed for network processing functions. Experimental results show that IXP425 gives better throughput compared to processors like Xeon and Pentium III [11].

We configure the IXP425 to connect to networks working on different technologies, and thus achieve seamless communication between heterogeneous networks. Network processors are used in many modern day routers due to their flexibility and speed. We propose to exploit this flexibility and the parallelism inherent in their architecture, to serve as an enhancement to the existing framework.

The rest of the paper is organized as follows. We discuss the related work in Section 2. We give a brief description of IXP425 in Section 3. We put forth our solution in Section 4. Section 5 concludes our paper along with our proposed future work.

2. Related Work

Carleton University has developed a testbed for WMNs [8] using IXP425 network processors as routers. They have used a modified version of Optimized Link State Routing Protocol (OLSR) developed by Communications Research Centre, Canada. This protocol supports Quality of Service over OLSR.

MCL has been developed by Microsoft Research for mesh environments [1]. MCL is described briefly in section 2.1.

Microsoft Research is working to develop technology that will make it easier and cheaper to provide people living in remote areas and small businesses operating in rural neighborhoods with faster internet connections. Microsoft has partnerships with seven universities to develop Mesh Connectivity Layer technology [12].

MIT Computer Science and Artificial Intelligence Laboratory (MIT-CSAIL) has come up with an experimental mesh network. They focus on link-level measurements of 802.11, to find high-throughput routes under lossy conditions [10].

2.1 MCL

Microsoft's Mesh Connectivity Layer runs in between the Data Link layer (layer 2) and the Network layer (layer 3). MCL routes using a modified version of DSR (an IETF protocol) called Link Quality Source Routing (LQSR).

2.1.1 LQSR:

Ordinary Ad-hoc routing protocols like DSR [2] are not efficient when implemented in WMN environments. These protocols do not exploit channel, range and data rate diversity of WMNs. WMNs using LQSR have been shown to perform better than WMNs using DSR [13]. In addition to hop count, LQSR uses the following metrics:

(a) Per-hop Round Trip Time (RTT)

Unicast probes are sent by every node to its adjacent nodes. Acknowledgement is sent for every probe message. Both the transmissions carry timestamps. Exponentially weighted moving average of the RTT samples is maintained by every node.

(b) Per-hop Packet-Pair (PktPair)

Every node sends a pair of probes to its neighbors. The first packet is small, and the second is big. The average in the delays of the reception of both the packets is measured.

(c) Expected transmissions (ETX)

The number of retransmissions required to send a packet from a node to its neighbor is given by ETX.

In LQSR, each node measures these qualities in its links to its immediate neighbors. This information spreads throughout the network during route discovery. The source then selects the best route based on the cumulative results.

3. Overview of IXP425

Intel's IXP425 Network Processor is built on Intel's XScale technology. It is a single-chip processor that supports high performance networking. The Processor runs at 533 MHz providing support for user-defined applications. It has a common architecture designed to facilitate gateway functions, Mini-DSLAMs (Digital Subscriber line Access Multiplexers) operations, wireless access point capabilities etc., [6, 7].

IXP425 comes with support for UART, USB v1.1, 33/66 MHz PCI v2.2 interfaces and SDRAM controller support.

4. Proposed Work

Our design maintains transparency throughout the network. The topology we envision is shown in Figure 2. It is an interconnection of 802.11x WLANs and Bluetooth networks with 802.11 mesh backbone. IXP425 devices act as router/gateways. We consider Bluetooth in our architecture, due to its rapid development and deployment in recent years. The architecture is not restricted to only 802.11x and Bluetooth, but can be extended to any network technology.

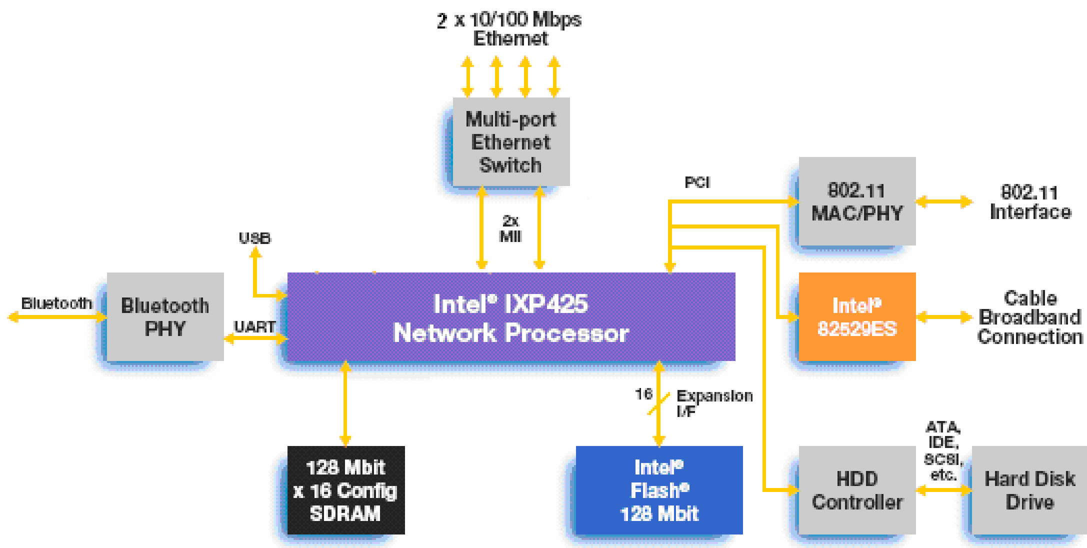

Figure 1: IXP425 Architecture

Independent devices without MCL capabilities can also become a node of the network.

We focus on the following types of nodes in our topology (Figure 2):

- *Network Processor based gateway/router (NP-G)*: It is an IXP425 loaded with MCL which acts as a router/gateway. E.g. NP-G1, NP-G2.
- *Bluetooth Terminal (BT)*: It is a Bluetooth enabled device without MCL support. E.g. BT1, BT2.
- *Mesh Point (MP)*: Any node with MCL capabilities is an MP. E.g. MP1, MP2.

All nodes running MCL on them, communicate using 802.11. Communication between nodes belonging to different technologies is facilitated in the network by NP-Gs. To achieve this, the NP-Gs maintain the network type, IP address and the corresponding MAC address for every node in the network it is connected to. The network processors do not maintain this information about the nodes which have MCL. Every entry has a timeout period and in case of inactivity of any node for the timeout period, the corresponding entry is removed. NP-G acts as a bridge between networks/nodes not having MCL and the backbone mesh network (WMN).

Communication between any two nodes in the heterogeneous design can be classified into four scenarios. We look into each one of them, and show how communication takes place.

Scenario 1: BT1 to BT2

Challenge: BT2 is not in the same network as BT1, and may not be within the range of BT1.

Solution: BT1 sends it to NP-G1; NP-G1 tunnels it inside 802.11 and transmits it using LQSR to NP-G2 through the WMN backbone. NP-G2 decapsulates the packet and sends it to BT2.

Scenario 2: BT1 to MP1

Challenge: BT1 and MP1 operate on different network technologies.

Solution: BT1 sends it to NP-G1. NP-G1 translates it to an 802.11 packet and sends it to MP1. Protocol conversion is done during translation, and LQSR is used to route the packet through the WMN to MP1.

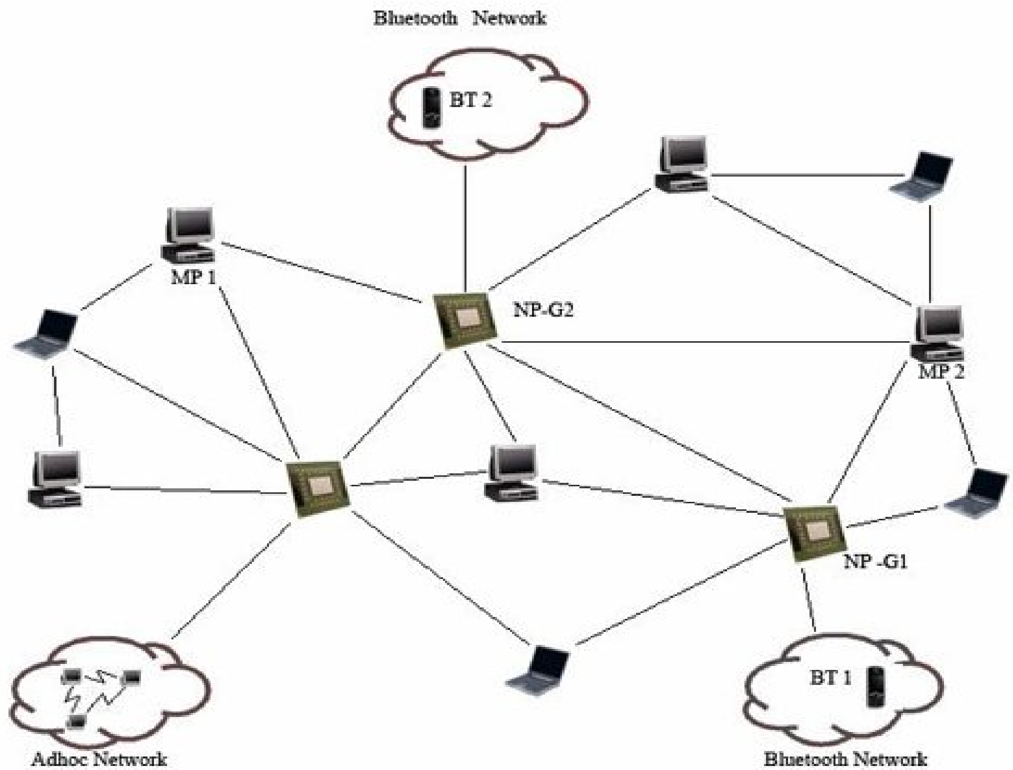

Figure 2 : Network Topology

Scenario 3: MP1 to BT1

Challenge: BT1 and MP1 operate on different network technologies.

Solution: MP1 sends the packet as an 802.11 packet using LQSR. The Network Processor NP-G1 understands that the destination is in the network connected to it. So it translates it into a Bluetooth packet and sends it to BT1.

Scenario 4: MP1 to MP2

LQSR is used in routing the packet from MP1 to MP2.

Independent devices running 802.11, but without MCL support, are treated similar to Bluetooth nodes. But they obviate the necessity for protocol conversion. When a packet is translated from Bluetooth to 802.11 formats or vice versa, protocol conversion is done as shown in Figure 3. For example, when a packet is sent from a Bluetooth node to an 802.11 node, and needs to be translated, the required information is extracted from the Bluetooth fields, and is appropriately mapped to create the 802.11 header. The resultant packet appears to have come from an 802.11 node. This design can also be extended to work with other network technologies.

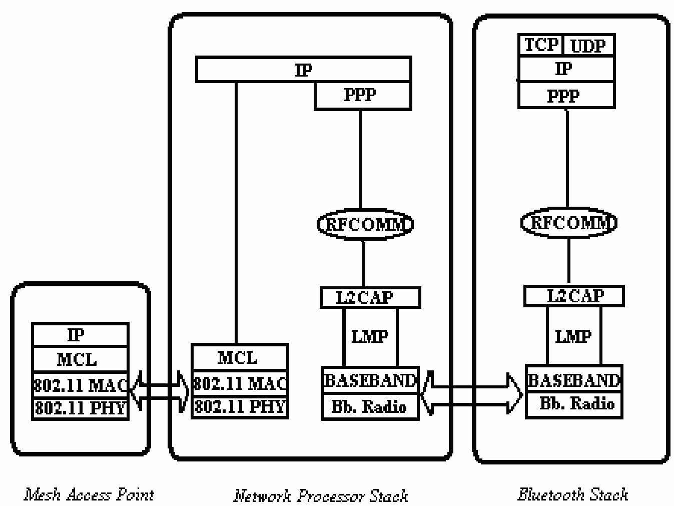

Figure 3: Stack for Protocol Conversion

4.1 Work in Progress

We are working on evaluating the performance of our heterogeneous design with IXP425s in comparison with the network operating without IXP425s.

5. Conclusion and Future Work

We expect the overall performance of the network to show significant improvement with the presence of IXP425s loaded with MCL acting as routers/gateways. The level of improvement achieved depends on the number of network processors incorporated in the system.

We are working towards optimizing the routing algorithm to take advantage of the features provided by the physical layer, like multi-radio and multi channel.

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