

Design and Implementation of Low Cost Microwave Full Duplex System based on WiFi Cards for Transmission over Long Distance

Ahmed Dooguy KORA , Valery NGUENGA TEZO

Telecommunications Systems Department, ESMT, Dakar - SENEGAL

kora@esmt.sn, nguenga@esmt.sn

Abstract— Rural areas in Africa have little access to information technologies because of the enormous cost of investments in telecommunications equipments. The aim of this paper is to design a microwave Full Duplex and full IP system based on WiFi technology in order to transmit data over long distance. This system could serve rural areas. Indeed, the cost of WiFi equipments is very affordable compared to other telecommunications equipments used for transmission over long distance such as optical fiber, WiMAX, VSAT and microwave systems .

Keywords— Microwave systems, low cost wireless systems, click.

I. INTRODUCTION

With the progress of Information and Communication Technology (ICT), effort has been made by governments of African countries to promote universal access. Many rural areas still lack access to Internet. However, in the case these areas have access to the Internet, the investment cost remains very high. These access problems are due to the fact that ICT operators must invest heavily in equipments to be deployed but these areas do not have many customers to enable these Internet Service Providers (ISPs) to recover the cost of investments. It is the reason why they abandon poor and low density places. Actually this financial constraint could be solved with low cost wireless network equipments. WiFi technology cards seem to be the best solution compared to optical fiber or VSAT and microwave systems usually used to serve rural areas.

A number of techniques have been already used to modify the Medium Access Control (MAC) layer using CSMA/CA protocol with WLAN cards by many researchers. Designers of WiLDNet [1] have implemented a protocol of sending a single acknowledgement for a series of packets which have been received. Thus, there is no acknowledgment to each packet. WiLDNet is also based on Time Division Multiple Access (TDMA). To migrate from CSMA/CA to TDMA, the driver of the Network Interface cards has been changed by disabling the combination of link layer (using the ad hoc mode), and disabling also the retransmission mechanism and the Automatic ACK. The CSMA has been disabled through the CCA (Clear Channel Assessment) of the chipset, so the radio card can transmit data continuously without waiting until the

channel is free. As in [2], changing the MAC layer protocol is performed using the software Click [3]. SoftMAC system [4] is a modification of the 802.11 MAC layer protocol. It uses multiple layer protocols for data binding. This system provides precise control of the content of the frames and the clock for the transmission and reception in wireless communications. To implement the system softMAC, the authors have ignored in the 802.11 MPDU (MAC Packet Data Unit) frames, the ACK frame and automatic retransmissions. These modifications are achieved by placing the card in monitor mode. The platform MadMac [5] allows reconfiguring the MAC layer of a wireless network card by using Atheros chipset. Test results have showed that the TDMA system established thanks to this platform has provided a flow rate improvement of 20% compared to CSMA. To implement this system, designers have had to disable some functions of the CSMA protocol as in the SoftMAC. In addition to it, the length of backoff is controlled by setting the values of CWmin and CWmax. The designers of this platform have used bidirectional UDP stream and ping test to assess the TDMA system implemented by the platform. It was done by using two computers with two wireless 802.11a/b/g Linksys cards.

The work of Ashish S. And al consist in a FreeMAC [6] platform with a linux system. The authors have proposed a mechanism for reducing latency in a TDMA system. As part of our project, we will use the software Click and the MadWiFi driver to manage our network card and router to implement the Full/Duplex on the WiFi.

This work focuses on the design and implementation of a Full Duplex's system based on wireless local network cards as WiFi to allow transmission over long distance. WiFi was first designed for short distance, so, in this project, WiFi cards are addressed to enable microwave transmission of data over long distance.

II. SYSTEM DESIGN

In this section, we describe our proposed system design of a full duplex microwave using WiFi network cards. CSMA/CA is a MAC protocol designed to solve access media conflict in a wireless LAN. Unfortunately this protocol is not suitable for transmission over long distance because of the acknowledgments of each received packet. Actually, when a

station sends an MPDU frame, the destination station should respond with an ACK frame after a delay of SIFS (Short Inter frame Spacing) time to indicate that it has received the packet. Thus, if the time exceeds the value contained in the duration field of MAC frame, the transmitter assumes that the packet is not received at its destination or there has been a collision. And then, the transmitting station tries to retransmit the packet. Acknowledgments reduce the system bandwidth. Similarly, the propagation delay introduced by long distance, decreases considerably the transmission rate of a link. Our idea is to modify the MAC layer protocol of WiFi cards by deleting acknowledgements and migrating the system originally using one frequency to a full duplex one like a classic microwave station thanks to two WiFi cards managed by click router software at each PC.

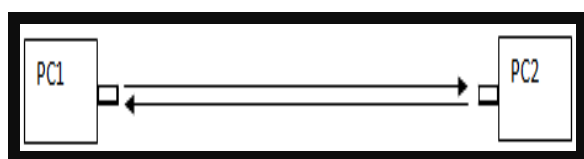


Figure 1. Traditional WiFi transmission scheme

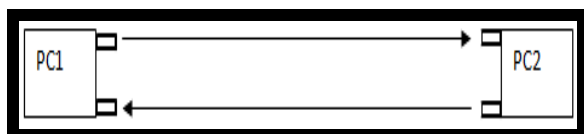


Figure 2. Full duplex microwave system using WiFi Cards

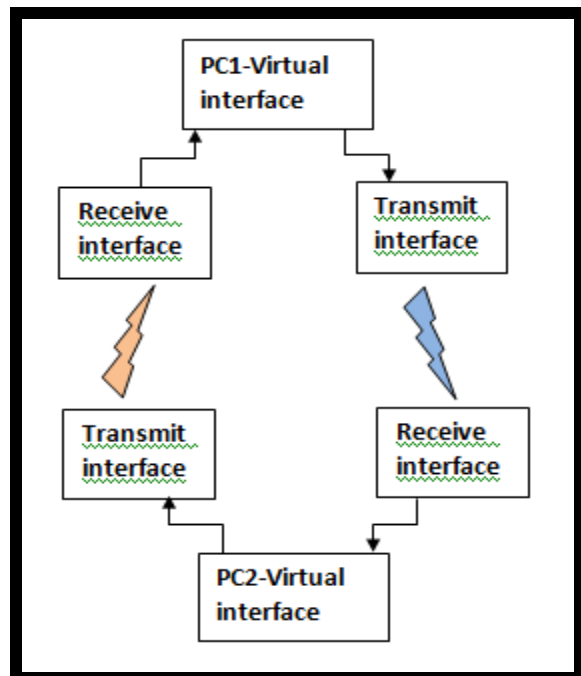


Figure 3. Proposed WiFi based full duplex system architecture

Figure 1 depicts a classic P2P WiFi link. It usually uses CSMA/CA which is a protocol managing asynchronous communication among many stations using the same frequency in both directions. Each station equipped with one card listens to the network before attempting to transmit its data.

A full duplex microwave system as represented in Figure 2 is a dedicated point to point communication system requiring one frequency for transmission in each direction.

Our system might be able to receive a ping request on one interface and reply to this ping with another interface. We have used a virtual host equipped with a virtual interface to achieve this scenario. Thus, the virtual interface is linked to the two real interfaces.

The designed microwave system in this work is well described in Figure 3. Two WiFi cards are considered at each station. Each card is allowed to transmit or receive only. Virtual interfaces at each side enable the routing of data.

The concept of software for routing packets has been proposed and implemented for the first time by Eddie Kholer [7]. This work focuses on the design of a modular router called Click Modular Router. The Click router can be executed either at the user level or as a Linux kernel module. Running a Click router as linux kernel module can increase performance and speed routing because there is less interaction with the upper layers. The project [8] shows that routers running click on a standard PC has more performance than commercial routers that cost more expensive. Click has been introduced in our design to allows the implementation of a new protocol. As in [9], Click has been used to develop and implement MPLS protocol in a PC. To set up a routing service with click, you must connect the elements together in a configuration file. This configuration file is a directed graph with elements at the top that allows packets to travel from one element to another as described by the graph. In our work, we have used Click as a linux kernel module.

In order to delete the acknowledgement, we have reconfigured the station in monitor mode thanks to Multiband Atheros Driver for WiFi (MadWifi) which can manage wireless cards that have an Atheros chipsets. MadWifi [10] is mainly under the GPL except a file called HAL (Hardware Access Layer). This is provided as a binary.

III. SYSTEM IMPLEMENTATION

Our implementation was done on two PCs running the kernel 2.6.24 of linux. We used TP-LINK cards based on Atheros chipset 2413, each card managed by the MadWifi driver. Moreover, unlike many other cards, the Atheros chipset allows to transmit data in "monitor" mode [4]. For our system, we need to disable certain functions of CSMA[11]. To achieve this, we put the cards in "monitor" mode, which will allow us to disable automatic acknowledgment and retransmission mechanism, listening virtual signalling channel and also the default MPDU format. Figure 4 depicts our way of transforming of the interfaces in monitor mode and the definition of the addresses and parameters of these interfaces in /etc/network/interfaces.

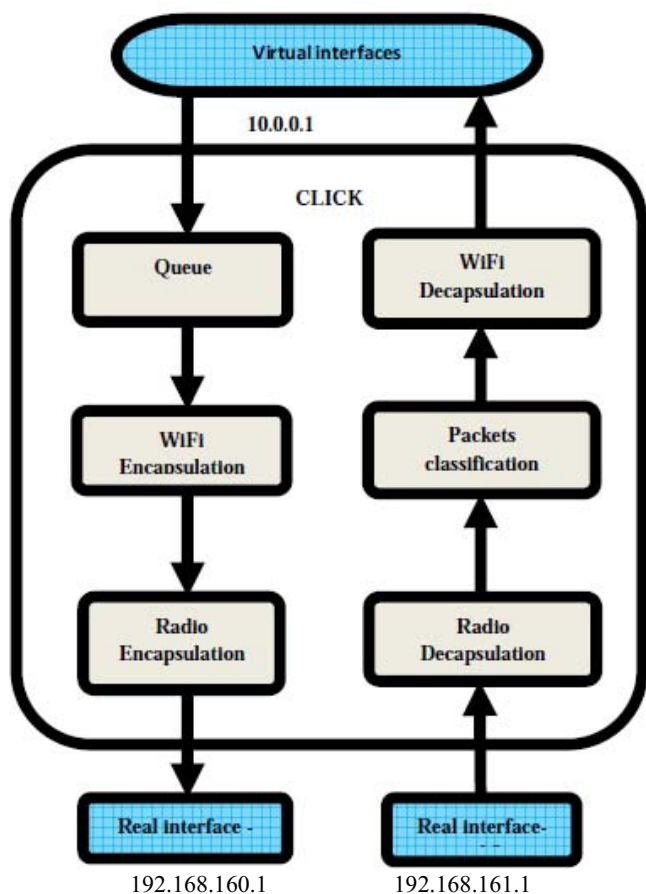


Figure 4. Detail of the implemented system architecture at each station

The Click router has enabled us to create virtual host with his virtual interface. We use the Click router because it can easily change the behaviour of a MAC layer by using elements that have basic functions of routing. It is also very effective for the processing packages especially if it is loaded as a kernel module. Using Click, a virtual interface has been created as shown in Figure 4 and IP packets from the Linux kernel were sent on this interface. The router Click allows to encapsulate the packets that are sent to the virtual interface in a WiFi frame and send it to the appropriate card. When data frames arrive on the interface, the router encapsulates the wireless frames into IP packets and transmits them to the virtual host which is responsible for transmission to the Linux kernel.

To summary, the click router intercepts the packets coming from upper layer at a virtual interface and then modify them before sending to the wireless card and vice versa.

IV. EVALUATION AND INTERPRETATION OF SYSTEM PERFORMANCE

This section is dedicated to show the proposed system performance. Because of financial limitation, the first step of our test has been performed in Lab. We have used Linux commands to set different distances and a number of pings test and file transfer via file transfer protocol (ftp) to evaluate the system performance. Thanks to Ubuntu, we have used a

network enabling us to estimate the average latency of 50 pings.

We have first we put a card in Access Point (AP) mode and configure another card as a station, and then, we have performed file transfer between these two computers. At the end of the transfer, we have obtained an average rate of 16,8 Mbps in one direction, and 8 Mbps in both directions simultaneously. We get an average time latency of 0.86 ms. In our case, we didn't get the theoretical throughput of 54 Mbps advertised by vendors.

The second test system consists of an adhoc network where the number of attempted transmission is 7, we have obtained an average time of 1.60ms and 86% of packets received successfully.

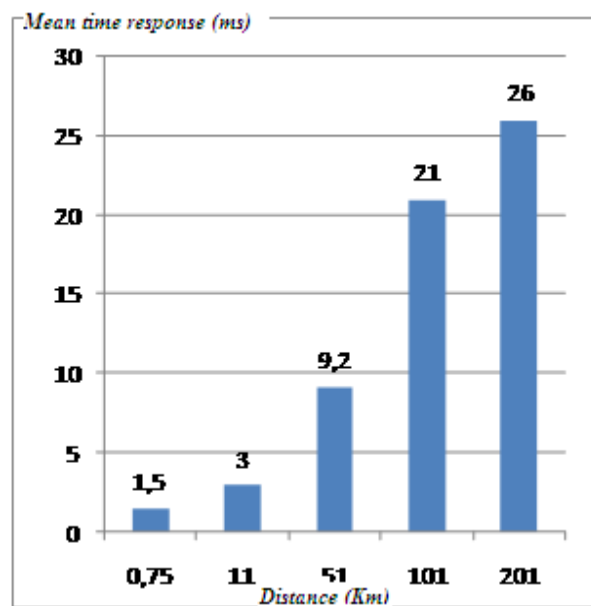


Figure 5. Mean time response to pings request

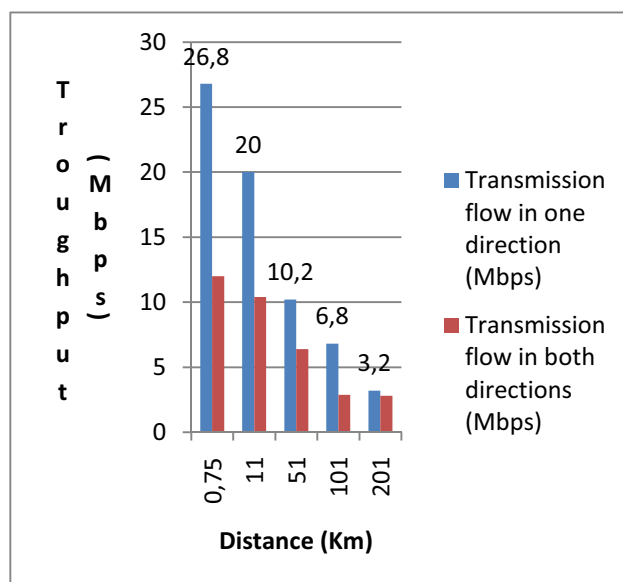


Figure 6. Example of an image with acceptable resolution

The transmission rate was approximately 6,4 Mbps for file transfer in one direction and 2,8 Mbps for file transfer in both directions. In this second test, the acknowledgments and retransmissions significantly affect the rate of the transmission.

In the third test, we disable the automatic acknowledgment by putting the number of retransmission attempts to 0 and evaluated the performance of an adhoc network based on the setting of the maximum distance between two PCs. Indeed, one can set the maximum distance between two PCs so that there is no collision between the ACK frame of the receiver and retransmission packets from the transmitter. Figures 5&6 show the average time latency of ping tests and throughput of file transfer based on the adjustment of the maximum distance of the microwave stations which are in this case, the two PCs used in this work. So, we noticed that when we set greater distance, the average time of response of ping request increases too and the throughput for file transfer decrease. This experiment shows the effect of long distance on WiFi.

In the fourth test corresponding to the proposed system. We have obtained higher performance than the third system which is an ad-hoc network with ACK parameters disable. This fourth system test provides an average time of 0,56 ms for the ping test, a rate of 28,8 Mbps for each unidirectional transmission. With this last system, we have noticed that distance do not have any effect in the transmission process. This experiment confirms that the designed system is adapted for the transmission over long distance.

V. CONCLUSIONS

In this project, we have designed and implemented a full duplex system based on WiFi cards for transmitting data over long distances. To achieve this, we have studied WiFi technology and related works of other researchers who have changed the behaviour of the MAC layer protocol of WiFi.

Our proposed microwave solution which performance is about 28,8 Mbps uses two WiFi cards at each station. The MadWiFi driver manage the network cards and Click Modular Router enable the implementation of the full duplex system.

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REFERENCES

- [1] R. Patra, S. Nedeveschi, S. Surana, A. Sheth, L. Subramanian, and E. Brewer, "WiLDNet: Design and Implementation of High Performance WiFi Base Long Distance Networks," *In NSDI '07: 4th USENIX Symposium on Networked Systems Design and Implementation*, Cambridge MA, USA, April 2007.
- [2] K. Chebrolu, B. Raman, S. Sen, "Long-Distance 802.11b Links: performance Measurements and Experience," *12th Annual International Conference on Mobile Computing and Networking (MOBICOM)*, Sep. 2006.
- [3] E. Kohler, R. Morris, B. Chen, J. Jannotti, and M. F. Kaashoek, "The Click Modular Router," *ACM Transactions on Computer Systems*, Aug. 2000.
- [4] M. Neufeld, J. Fifield, C. Doerr, A. SHETH, and D. Grunwald, "Softmac flexible wireless research platform," *In Fourth Workshop on Hot Topics in Networks (HotNets)*, Nov. 2005.
- [5] A. Sharma, M. Tiwari, and H. Zheng, "MadMAC: Building a Reconfigurable Radio Testbed Using Commodity 802.11 Hardware," *In WSDR '06: First IEEE Workshop on Networking Technologies for Software Defined Radio Networks*, Reston, VA, USA, September 2006.
- [6] Ashish Sharma, Elizabeth M. Belding, "FreeMAC: Framework for Multi-Channel MAC Development on 802.11 Hardware," *PRESTO '08*, Aug. 2008, Seattle, USA
- [7] E. Kohler, "The Click modular router," PhD thesis, *Massachusetts Institute of Technology*, Nov. 2000.
- [8] Nandesh Kumar Palanisamy, "Modular Implementation of Temporally Ordered Routing Algorithm," *University of Colorado*, 2001.
- [9] Sami Ruponen, "Development of a MPLS Transport Profile Network Element using Click modular router," Master's Thesis Seminar, *VTT Technical Research Centre of Finland*, April 2009.
- [10] <http://www.madwifi.org>
- [11] *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification*, IEEE Std. 802.11™, 2007.