FPGA based implementation of Interoperability of Wireless mesh Network and Wi-Fi

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Abstract: Wireless Mesh Networks (WMNs) is a key technology for next generation wireless networks, showing rapid progress and many new inspiring applications. IEEE 802.11s is the standard defined for WLAN mesh networks. One important characteristic of WMNs is various heterogeneous networks such as Wi-Fi, Wi-Max, sensor and cellular network can be integrated with Wireless Mesh Networks. Different types of networks use different standards for their communication. In this paper, the heterogeneous networks is discussed and how they can be interoperable with the IEEE 802.11s based WMNs and this proposed the model contains FPGA based algorithm to convert Wi-Fi standard to IEEE 802.11s -a mesh standard.

Keywords: WMNs, WiMax, FPGA, WLAN, HDL

I. INTRODUCTION:

Interoperability is the ability of the two networks to exchange information and to use the information exchanged. Here the two networks used are WMN and WiFi.

WMN is a communications network made up of radio nodes organized in to mesh topology wireless mesh network often consists of mesh clients, mesh routers and gateways. The coverage area of radio nodes working as a single network is sometimes called as mesh clouds. Access to his mesh cloud is dependent on the radio nodes working in harmony with each other to create a radio network. A mesh network offers redundancy, when one node can no longer operate, the rest of the nodes can still communicate with each other directly or through one or more intermediate nodes.

A mesh network is a special type of adhoc network, it often has a more planned configuration and may be deployed to provide dynamic and cost effective connectivity over certain geographical area.

Wireless mesh network can selfheal and selforganise. And wireless mesh network can be implemented with various wireless technologies including 802.11, 802.15 and 802.16 cellular technologies or combination of more than one type.

Wireless Fidility is the most popular wireless communication standard. WIFI technology was almost solely used to wirelessly connect laptop computers to internet via LAN. With Wi-Fi it is possible to create wireless LAN. Wi-Fi is used to provide high speed connections to laptop computers, desktop computers and PDAs. The 802.11 standard are classified into 20 different standards.
The 802.11 standard reserve for the low levels of OSI model for wireless connection. 802.11 different standards are 802.11 a to 802.11j.

II. ARCHITECTURE OF WMN AND WI-FI:

A. *Architecture of WMN*

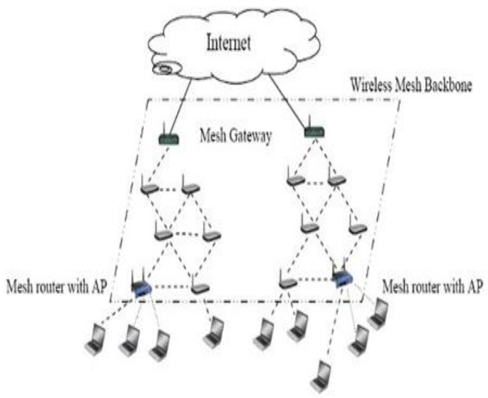

Fig. 1: Architecture of WMN

WNN consists of two types of nodes: Mesh routers and mesh clients as shown in Fig. 1.

Wireless mesh router contains additional functions to support mesh networking. It is equipped with multiple wireless interface built on either the same or different wireless access technologies.

Wireless mesh router can achieve the same coverage as a conventional router but with mesh lower transmission power through multihop communications. Intermediate nodes not only boost the signal, but co-operatively make forwarding decisions based on the knowledge of the network.

B. Architecture of WiFi:

Fig. 2 shows the three most important items which makes working WiFi in laptop.
These are

- Radio signals
- WiFi cards which fits in computer.
- Hotspot which create WiFi network

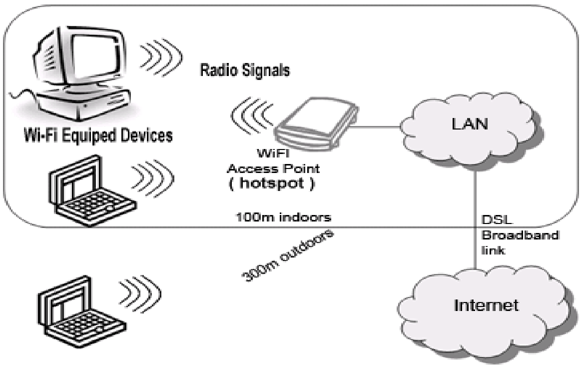

Fig. 2: Architecture of Wi-Fi

Radio Signals:

Radio Signals are the keys which make Wi-Fi networking possible. These radio signals transmitted from Wi-Fi networking possible. These radio signals are transmitted by Wi-Fi antennas and are picked up by Wi-Fi receivers such as computers and cell phones that are equipped with Wi-Fi.

Wi-Fi Cards:

Wi-Fi cards can be external or internal, if Wi-Fi card is not installed our compute. USB antenna can be purchased and it acts like a Wi-Fi card.

Wi-Fi Hotspots:

A Wi-Fi hotspot is created by installing an access point to an internet connection. The access point transmits a wireless signal over a short distance, typically covering around 300 feet.

III. BASIC STRUCTURE OF 802.11 AND 802.11S

A. Structure of WLAN and 802.11s Mesh topology

The Fig. 3 and Fig. 4 shows the basic structure of WLAN topology and 802.11s mesh topology respectively. Normally WLAN 802.11 operates in infrastructure mode. The stations will be connected to different access points which act as a central device and also operates as a gateway to non-802.11 networks. All the APs will be connected to the wired network.

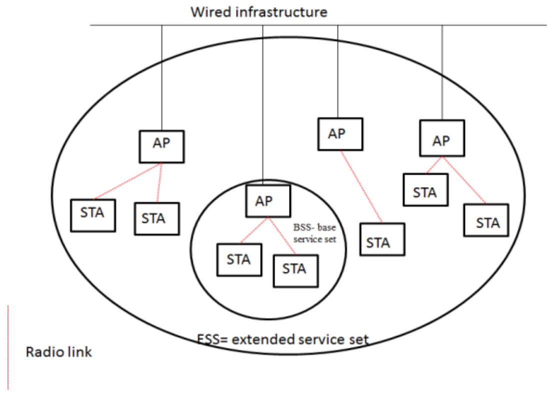

Fig. 3: Classic WLAN 802.11

In 802.11s mesh topology consists of stations, Mesh Access Points (MAPs) and mesh portals. The stations are connected with mesh APs and some MAPs forward traffic to and from the other MAPs which acts as Gateway. This work uses packet conversion algorithm to make the frame structure compatible with each other to perform interoperability between WMNs and Wi-Fi. In the frame structure, by making use of using MAC data header for the identification of distributed network and also for address decoding.

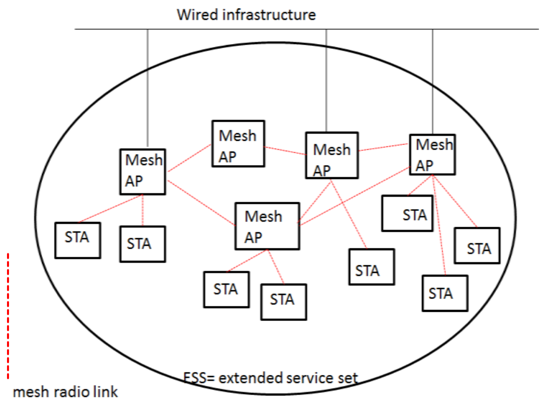

Fig. 4: 802.11s mesh topology

B. MAC Frame format of 802.11

bytes	2	2	6	6	6	2	6	0-2312	4
	Frame Control	Duration/ ID	Address 1	Address 2	Address 3	Sequence number	Address 4	Data	CRC

Fig. 5: 802.11 Data Frame Structure

The IEEE 802.11 WLAN defines 3 types of frames such as data, control and management frame. Data frames carry higher- layer data. Control frames are used for acknowledgments and reservations. Management frames are used to set up, organize, and to maintain a WLAN and the local link. The Fig 3.3 shows the MAC data header format, and the brief description of each field is given below.

Frame control: The protocol version will be given in the frame control field. Type and subtype fields are used to identify the data frame, control frame and management frame. ToDS will be '1' if the packet is destined to distributed system or within the same BSs. FromDS will be '1' if the frame is transferred from the distributed system.

Duration ID: Depending upon the frame type, this will perform different operations. It will be station ID for power save poll messages. For other frame, this duration is for the NAV calculations.

Depending upon the ToDS and FromDS value the frame may have upto four different address fields.

Address1: If ToDS=1, it will always represent the recipient address of the AP or else it is the address of the end station.

Address2: If FromDS=1, it will be address of transmitter AP or else it is the address of the station.

Address3: If FromDS=1, then address 3 is the original source address. If ToDS=1, it will be the destination address.

Address4: When wireless distribution system involved in the communication this address field will be used. For this case, both ToDS and FromDS will be set and original source and destination address is missing.

Sequence Control: There are two subfields in these sequence control. Fragment number and sequence number which are used to define the frame and number of arrangements in the frame. This is also used to represent the order of different fragment of same frame and to identify the duplication of packets.

CRC: It is a 32-bit field which is used to perform the cyclic redundancy check.

C. *MAC Frame format of 802.11S:*

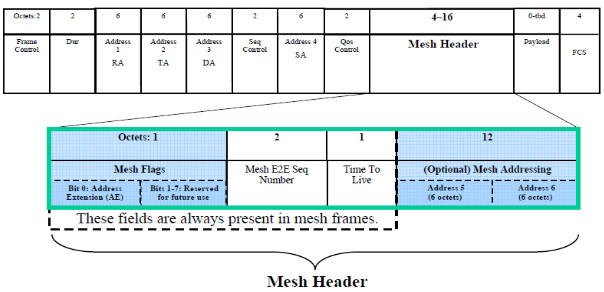

Fig.6: 802.11s Data Frame Structure

In addition to IEEE 802.11, to provide multi hop, 802.11s extends data and management frames by an additional mesh control field. The above Fig3.4 depicts the frame format of 802.11s.The structure mesh header is as follows.

Mesh Flags: Mesh Flag field contains two fields. First bit is for address extension (AE flag). If this flag is set, six address schemes will be used by AP. This extra address fields used by the intermediate MPs in the mesh path. The second fields with remaining seven bits are reserved for future use.

Mesh E2E Sequence Number: This field used for the identification of frames and also for the detection of duplication inside the mesh network. The receiver of the frame uses this sequence number to avoid duplicates during the frame broadcasting.

Time to Live: This field will be decremented for each node. When it becomes zero the packet will be discarded. This is used to avoid endless retransmission in case of looping.

Mesh Addressing Extension: When two stations (which are not in the mesh network) communicating through mesh network, there is need of mesh source and destination address. The AE flag, as mentioned earlier, indicates the existence of the optional address extension field including Address 5 and Address 6 in the Mesh Header. SA will represent the address of the MAP which originates the transmission in the mesh network. Likewise DA represents the address of the MAP from which, the nonmesh station receives the packet.

IV. INTEROPERABILITY OF MESH NETWORK WITH WIFI

Whenever the data packets communicate to and fro from heterogeneous network, the following tasks should be accomplished.

- Frame receiver module
- Frame identification and address decoding module
- Frame conversion module

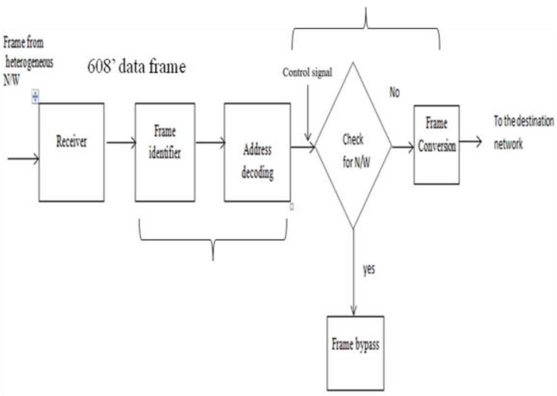

Fig. 7: Block diagram of the system

The Frame from the heterogeneous network is received by the receiver, frame identification module identifies the frame and address decoding is performed, then type of the network is determined, if the frame is from the same network, it bypasses the frame, if the frame is from the heterogeneous network frame conversion will be performed and forward it to the destination network.

As the frame is received by the receiver module, it checks for the five types of different errors occurred as shown in fig 3.6. The simulation result is tested for all kinds of errors.

Fig 8 illustrates the implementation of WMNs to perform frame identification and address decoding. This module composed of Frame Detector, Frame synchronizer and decoding modules. The frame from the RF front end will be detected by the packet detector and it will check whether it is a mesh frame or the frame is from the other networks.

There are separate decoding units for WMNs and for other heterogeneous network frames. The frames will be separately processed and stored in the storage buffer. After MAC header decoding, the destination address field of the frame will be found and the corresponding control signals will be given to frame conversion module for the further processing of the frames.

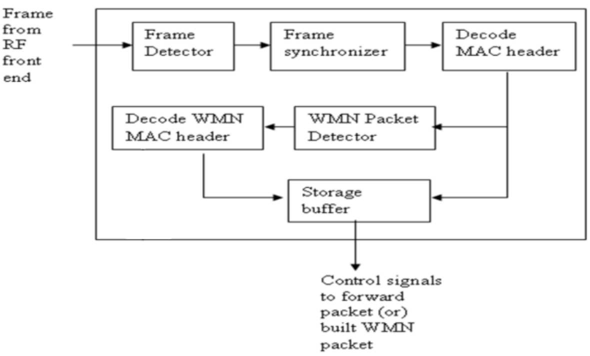

Fig. 8: Frame Identification and Decoding Module

Fig. 9 shows the proposed frame conversion module of the WMNs. The received control signal from the frame identification module will help to identify the frame. If the frame has from and destination address to mesh network, then it will be transmitted to the medium access sublayer.

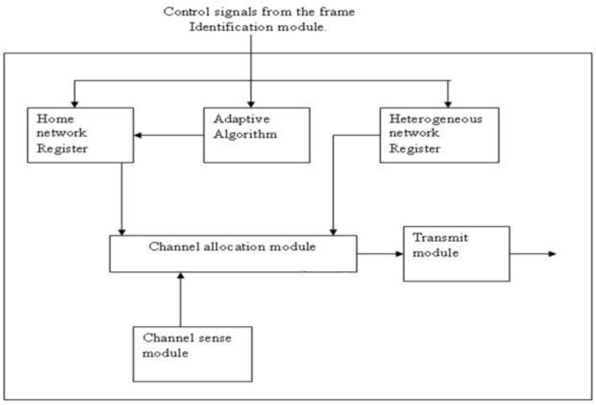

Fig. 9: Frame Conversion Module

If the frame received from the heterogeneous network destined to mesh network, then it will be processed by the adaptive algorithm where necessary frame conversion will be done and then to the MAC sub layer. If the packet is destined to the Wi-Fi network then it is directly given to Wi-Fi network register and transmitted. Frame computing module permits to build the frame based on the received frame subtype.

The channel availability module will verify the channel availability by sending the carrier sense signal of the physical layer and the value of Network Allocation Vector (NAV) that is provided by the NAV register. If the medium is available the frame will be transmitted through the transmitter frame module. If the medium is not available it will waits for a certain time that is determined by the BACKOFF ALGORITHM.

V. PERFORMANCE ANALYSIS

The receiver module will identify the different types of errors to avoid the receiving of erroneous frames. The errors are classified into five types*e_op1*, *e_op2*, *e_op3*, *e_op4* and *e_op5.*

Event	Error results
When SOP and EOP occurs at the same time	e_op1
When byte count is more than 76 bytes	e_op2
When SOP comes twice	e_op3
When EOP comes twice	e_op4
When cycle count is more than 128	e_op5

Table 1 : List of Errors

When the start of packet *(sop)* and the End of packet *(eop)* occurs at the same time frames will not be received and this is indicated by the signals *error_out* and *e_op1* are set to high as shown in Fig.10.

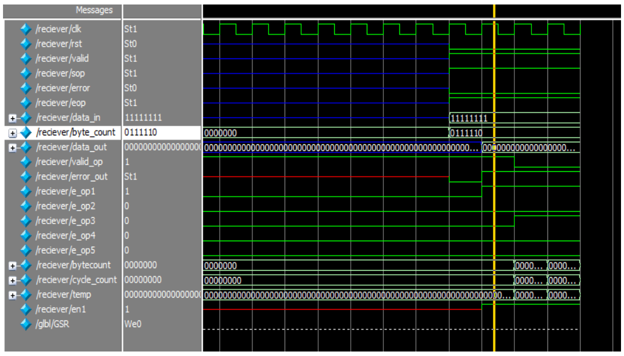

Fig. 10 : simulation result for e_*op1*

The second errors *e_op2* will occur, if the byte count is more than 76 bytes, then the *error_out* will get high signal and the *e_op2 is set to 1*.The third errors *e_op3* will occur, if the signal *sop* becomes high twice, then *error_out* will get high signal and the *e_op3 is set to 1*, as shown in Fig.11.

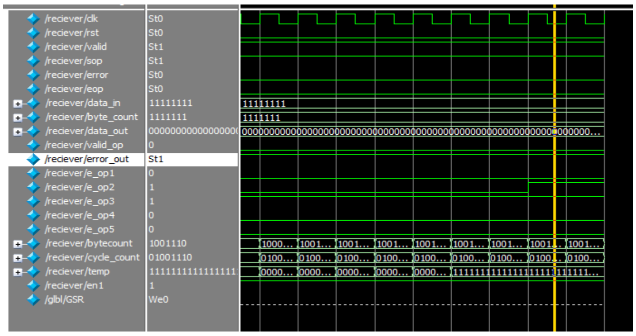

Fig.11: Simulation result for e_ op2 and e-op3

The fourth errors *e_op4* will occur, if the signal eop becomes high twice, then *error_out* will get high signal and the *e_op4 is set to 1*, as shown in Fig.12.

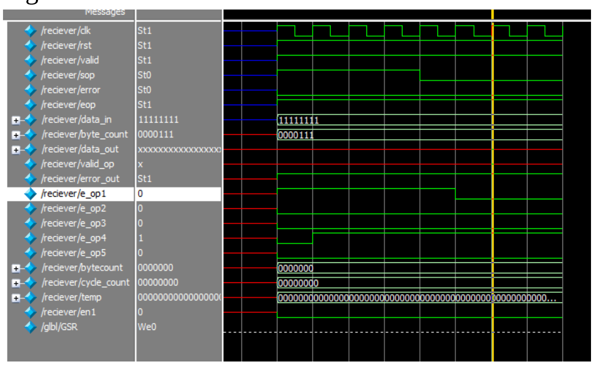

Fig.12: Simulation result for e_ op4

The fifth errors *e_op5* will occur, if the cycle count exceeds 128, then *error_out* will get high signal and the *e_op5 is set to 1*, as shown in Fig.13.

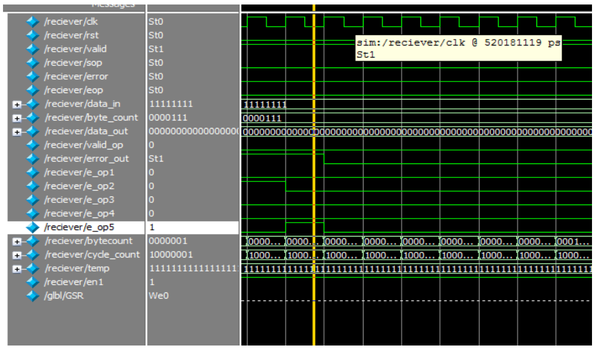

Fig.13: Simulation result for e_ op5

Frame identification and decoding module identifies the Ethernet header and IP header from the valid received data. The separated headers are as shown in the simulation result of Fig. 14.

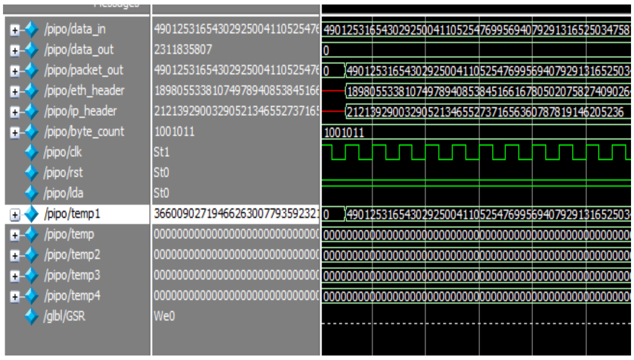

Fig.14: Simulation result for Frame identification module

Depending on the source and the destination address of the network data will be transmitted.

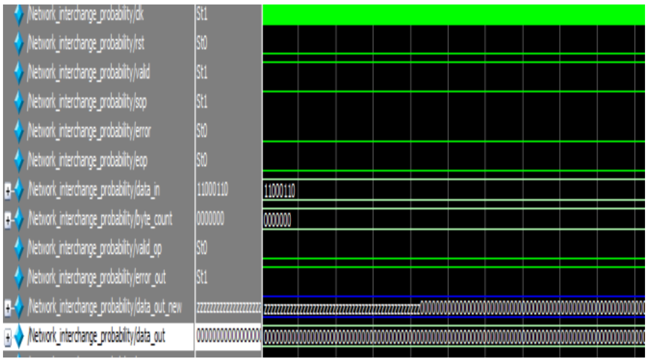

Fig.15: Simulation result for network interoperability module

Advantage of Hybrid mesh network:

- HWMN is cheaper to install and will offer better return on investments.
- HWMN nodes automatically find each other to form mesh network and can continue the operation even if node is taken offline.
- HWMN has minimum system latency, enables high speed broadband internet access.

VI. CONCLUSIONS AND FUTURE WORKS

Low cost of the Wi-Fi and new features of WMNs makes it ideal technology. The receiver module And the Frame identification module is implemented which gives the satisfactory output. This deals with delivering data at faster rate.

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