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An Energy Consumption and Improved, Qos Using Energy Aware Routing Algorithm for Video Delivery

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Abstract: Several research works are done that provides advanced routing mechanisms with the goal to either increase delivery performance or encourage energy saving. But does not well focus on video delivery, security and QOS. This project proposes E-Mesh, an energy-aware wireless routing algorithm with Vector Quantization Based Encryption algorithm which balances the need for energy saving with that of maintaining good quality of video content. E-Mesh is positioned at the network layer and works in conjunction with an energy-aware MAC-layer duty cycle management scheme. Simulation was done and the performance of E-Mesh with VQ based encryption. Results demonstrate that E-Mesh with VQ based encryption obtains up to 29% energy savings at the same content delivery quality level that is compared with an IEEE 802.11s routing protocol.

Keywords: Energy consumption, vector quantization, video delivery, quality of service

I. Introduction

A Wireless Mesh Network (WMN) is a communications network made up of radio nodes organized in a mesh topology. It is also a form of wireless ad hoc network. Wireless mesh networks often consist of mesh clients, mesh routers and gateways. The mesh clients are often laptops, cell phones and other wireless devices while the mesh routers forward traffic to and from the gateways which may, but need not, be connected to the Internet. The coverage area of the radio nodes working as a single network is sometimes called a mesh cloud. Access to this mesh cloud is dependent on the radio nodes working in harmony with each other to create a radio network. A mesh network is reliable and 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. Wireless mesh networks can self-form and selfheal. Wireless mesh networks can be implemented with various wireless technologies including 802.11, 802.15, 802.16, cellular technologies and need not be restricted to any one technology or protocol. This article introduces an energy-aware wireless routing algorithm E-Mesh [4] which works on top of the classic OLSR [5] protocol and makes use of a novel multiplication based utility function when determining the best route for traffic delivery. This function combines utility components which reflect remaining energy level, transmission distance and network load. E-Mesh works in conjunction with AOC-MAC [6], an energy-aware router duty cycle management scheme in order to manage the sleep-periods of the network devices in a smarter way based on link-state communication condition and to reduce the energy consumption of routers by extending their sleep-periods. E-Mesh is illustrated and tested for quality-oriented energy-aware video deliveries over wireless mesh networks.

II. Infrastructure Of Wireless Mesh Network

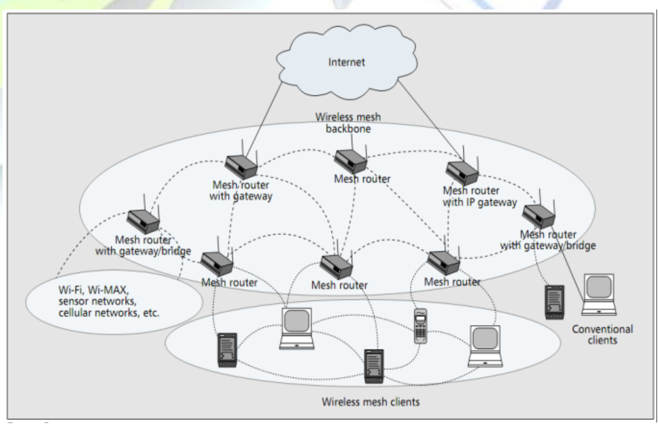

Fig 1 Infrastructure of Wireless Mesh Network

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Wireless mesh infrastructure is, in effect, a network of routers minus the cabling between nodes. It's built of peer radio devices that don't have to be cabled to a wired port like traditional WLAN access points (AP) do. Mesh infrastructure carries data over large distances by splitting the distance into a series of short hops. Intermediate nodes not only boost the signal, but cooperatively pass data from one point to another point by making forwarding decisions based on their knowledge of the network, i.e. perform routing. Such architecture may, with careful design, provide high bandwidth, spectral efficiency, and economic advantage over the coverage area. Wireless mesh networks have a relatively stable topology except for the occasional failure of nodes or addition of new nodes. The path of traffic, being aggregated from a large number of end users, changes infrequently. Practically all the traffic in an infrastructure mesh network is either forwarded to or from a gateway, while in ad hoc networks or client mesh networks the traffic flows between arbitrary pairs of nodes.

III. Architectures Of E-Mesh

While the video content is being streamed from the remote server to the user device, the video data packets pass through multiple routers in the wireless mesh network along the delivery route. Depending on the traffic conditions and network topology variation in the wireless mesh network, this delivery route may change. The network operators of mesh routers desire to reduce the energy consumption on their network, while ensuring the QoS provisioning of the video streaming services. To achieve this, the network operators can deploy E-Mesh, which offers an innovative way to balance energy consumption, network load and connectivity for mesh routers during the video stream.

E-Mesh is based on the following assumptions:

• The maximum communication ranges of the mesh nodes (i.e., mesh router, mesh data source and mesh client) are the same (defined as K).

• Each mesh node ni has the capability to determine its position in terms of coordinate (Xi,Yi) and to measure its remaining energy level Ei and traffic load Li.

• The time for the client to get the information from the routers (such as their position and remaining energy level) is very short in comparison with data transmission time and the client movement time scale.

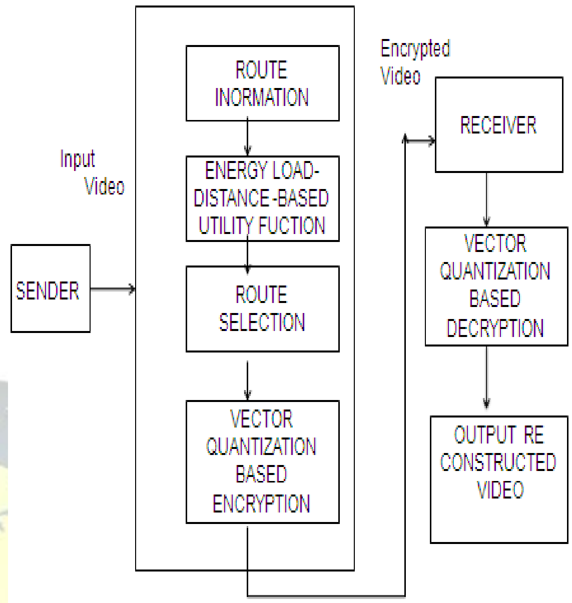

Fig 2 Block diagram of E-mesh

IV. Modules

Route Information Collector

This module is in charge of collecting network/ device-condition-based information from the mesh routers, including the remaining energy levels at each mesh router, current traffic load amount and distance between mesh routers, calculated using the position of each router. The information is used when computing by the utility function to assess the general condition of all the nodes in the wireless mesh network, in order to select the most suitable route for traffic delivery in terms of the least energy consumption on the mesh routers, optimal traffic load amount on the mesh routers and distance between routers within their maximum communication range. The information is collected from the headers of the ATIM packets sent by the PHY layer and forwarded by the MAC layer. The messages are stored and updated in a global route information table in which the utility function obtains the information as it needs. The process of the information collection is illustrated in Fig 3

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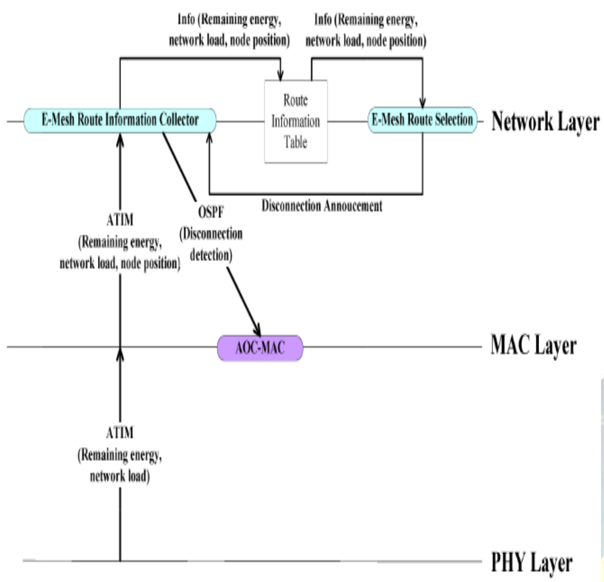

Fig 3 Network/device-condition-based information between different OSI layers

The information of remaining energy and current network load of each mesh router is included in the ATIM packets by the PHY layer and sent to the MAC layer. After the MAC layer receives the packets, the information of (X, Y) position of each mesh router is added to the headers and the packets are forwarded to the network layer where E-Mesh obtains such information and stores them in the global route information table. The duty cycle of each mesh router is controlled with the MAC-layer solution AOC-MAC, which periodically observes the communication states of the mesh routers included in the ATIM packets from E-Mesh and adjusts the length of the active periods of the mesh router in the duty cycle according to the communication states.

Energy-Load-Distance-Based Utility Function

The responsibility of the Energy-Load-Distance Utility Function module is to calculate the utility for each mesh router to enable choosing the next hop for the traffic from the neighbor mesh routers of the current mesh router. The neighbor mesh router with the optimal utility value will be selected as the next hop of the traffic and it will search for its next hop with the utility values of all its neighbor routes recalculated. In the wireless mesh network topology shown in Fig. 3, each mesh router ni considers the following three key criteria for utility calculation: its local position in terms of the (Xi, Yi) coordinates, its current network traffic load Li and its remaining energy Ei. The remaining energy and network traffic load for each mesh router are updated periodically during the video streaming traffic delivery. Hence for each mesh router ni, the Energy-Load-Distance-based utility function is shown in equation. It relies on the following components as described in equations

Remaining energy score $E(n_i)$:

$$\mathbf{E(n_i) = E/Emax}$$

Distance score $D(n_i)$:

$$\mathbf{D(n_i) = D - D_{min}/D_{max} - D_{min}}$$

Load score $L(n_i)$:

$$\mathbf{L(n_i) = L - L_{min}/L_{max} - L_{min}}$$

$$\mathbf{C(ni)=\frac{L(ni)^{wl}*D(ni)^{wd}}{E(ni)^{we}} \quad (L<=i<=N)}$$

In above equation W_e, W_d and W_l are adaptive weight factors for the utilities, respectively. The weights represent the importance of the different utilities in the route selection. The values of the weights are decided by the network operators of the mesh nodes in the wireless mesh network, depending on different possible demands on various situations. For example, the value of W_e is set higher in the case that the energy consumption is considered more important. On the other hand, if the network operator cares more about network load, the values of W_l can be set higher. As already mentioned, N represents the total number of mesh routers in the wireless mesh network.

Route Selection

Based on the utility calculation results provided by the Energy-Load-Distance Utility Function module, the Route Selection module is responsible for picking the mesh routers with the optimal utility values hop by hop, starting from the router closest to the remote server and ending at the router closest to the mesh client, to build the optimal traffic delivery route balancing the energy-load-distance criteria. The utility-optimal route is updated periodically by this module, according to the change of network conditions and routing device characteristics. When no neighboring mesh routers are detected during the routing process, a disconnection announcement is made in the form of a 0-1 bit message (0 represents no disconnection and 1 represents disconnection) and sent to the Route Information Collector module. After receiving the disconnection announcement, the Route Information Collector module stores the 0-1 bit announcement message into the OSPF packet headers before sending the OSPF packets to the MAC layer. The disconnection announcement is then used by the MAC-layer protocol as the link state information.

Vector quantization

The high correlation among neighboring blocks is the key feature exploited in VQ to predict the current block during encoding, where a state codebook is generated according to the side-match prediction, and the original VQ codebook is called the super codebook. The side-match prediction assumes that the

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values of adjacent pixels among the neighboring blocks are equal. In VQ, the blocks locating in the first row and the first column of a VQ-compressed image are encoded using the super codebook, and the remaining blocks are predicted using the state codebook. The relationships among the encoding block X, its top neighboring block T, and its left neighboring block L for blocks of size 4×4. This vector quantization denotes the border vector and the side vector of block X as ,

$$\mathbf{B(X) = (X_1, X_2, X_3, X_4, X_5, X_9, X_{13})}$$
$$\mathbf{= (b_1, b_2, b_3, b_4, b_5, b_6, b_7)}$$
$$\mathbf{S(X, T, L) = ((T_{13} + L_4)/2, T_{14}, T_{15}, T_{16}, L_8\ L_{12}, L_{16})}$$
$$\mathbf{= (s_1, s_2, s_3, s_4, s_5, s_6, s_7).}$$

The squared Euclidean distance is employed to measure SMD between the encoding block X, predicted by blocks T and L, and a codeword c_w in the codebook, as follows: VQ with a selected state codebook size, most of the indices can be predicted by the state codebook and the VQ indices are mostly close to zero. To yield an extra space for hiding secret data, frequently used indices are encoded by short codes while rarely used indices are encoded by long codes. Thus, a VQ index is encoded using a 1-bit indicator concatenating an VQ index when the VQ index can be predicted by the state codebook; a VQ index is encoded using a 1-bit indicator concatenating the original VQ index when the VQ index cannot be predicted by the state codebook. As a matter of fact, simulation results show that this arrangement can improve the compression performance.

$$\mathbf{SMD(X,c_w) = D(S(X,T,L)(c_w)) = \sum_{i=1}^{7}(s_i-b_i)^2}$$

The entropy of the encoding result can be reduced when the SMVQ is exploited, which yields an extra hiding space to hide secret data. One of the areas on the top or left of the currently encoding index, named the prediction index, is used to predict the encoding index and generate the state codebook. In general, the neighboring blocks have low correlations with those blocks locating at the extremely non smooth regions, and vice versa. For blocks with high correlations, the prediction index can better predict the encoding index, and vice versa. In the VQ process, when two neighboring blocks with high correlations are replaced with indices, the correlations may not be existed.

To maintain the correlations of the two neighboring indices, the codeword in the codebook are sorted according to the mean values and variance values of the codeword before the VQ encoding is performed. In the sorting process, only the smooth codeword (with low variances) are sorted using means and variances, while the no smooth codeword's (with high variances) are not sorted. The value of *p* is determined by the variance of a codeword. Given a codeword, if the corresponding variance is greater than a threshold, *V*−th, the codeword associates to a no smooth block and *p* is 0. Otherwise, the codeword associates with a smooth block and *p* is 1. In the embedding process, the encoding index, namely base index, locating in the first row and first column of a VQ-compressed image remains unchanged. Indices associated with the first row (column), except for the first one, uses the left (top) index as the prediction index. Other indices can be predicted using horizontal or vertical prediction, where a left index is used as a prediction index for horizontal prediction, while a top index is used as a prediction index for vertical prediction. A predictable index can be a short index, middle index, or long index according to the prediction accuracy. short index is used to embed secret data, and a middle index is utilized to compress the code stream.

V. RESULT AND DISCUSSION

Fig 4 Source video frame

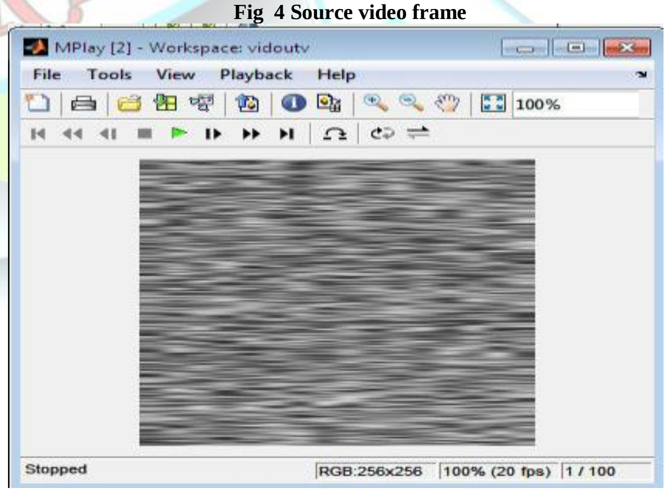

Fig 6 Encrypted video frame

The video content streamed from remote server to user device, the video data packets pass through multiple routers. Depends on the traffic conditions & network topology variation in the wireless mesh network, this delivery route may change. The mesh routers are to reduce the energy consumption on their network, while ensuring the QoS provisioning of the video streaming services. To achieve this, by deploy E-Mesh, which offers an energy consumption, network load & connectivity for mesh routers during the video delivery The remaining energy and network traffic load for each mesh router are updated periodically during the video streaming traffic delivery.

Fig 5 Received video frame

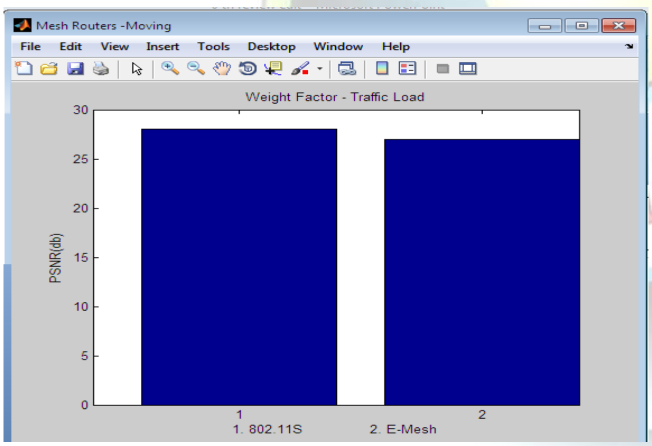

Fig 7 PSNR achieved with variable weights on traffic load when the routers are static

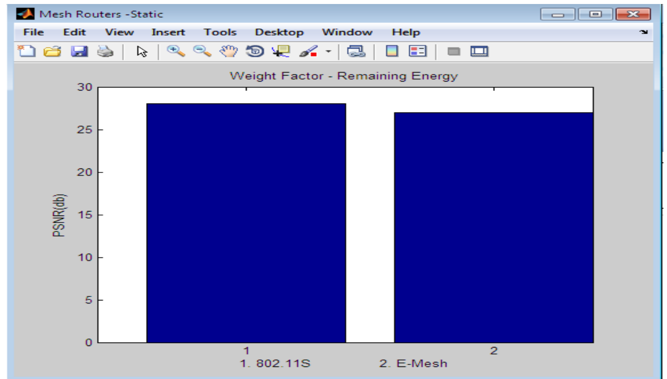

Fig 8 PSNR with variable weights on traffic load when the routers are moving

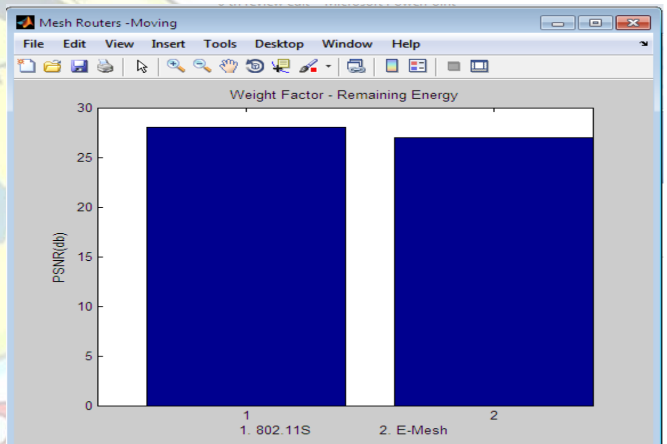

Fig 9 PSNR achieved with variable weights on remaining energy when the routers are static

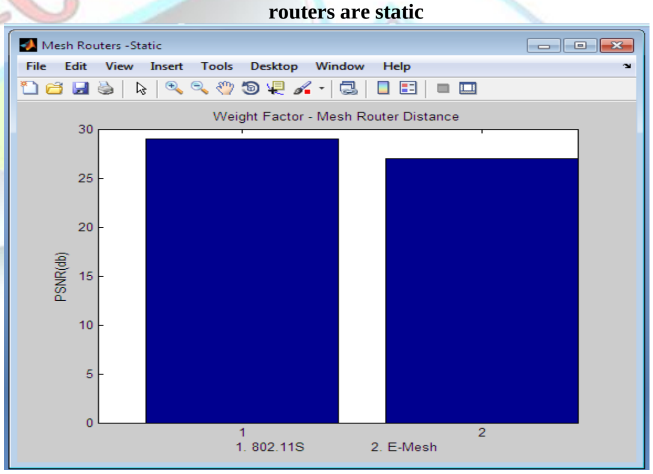

Fig 10 PSNR achieved with variable weights on remaining energy when the routers are moving

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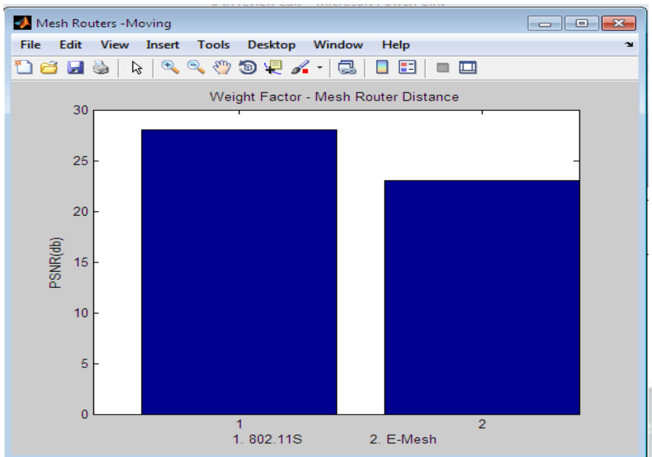

Fig 11 PSNR achieved with variable weights on mesh router distance when the routers are static

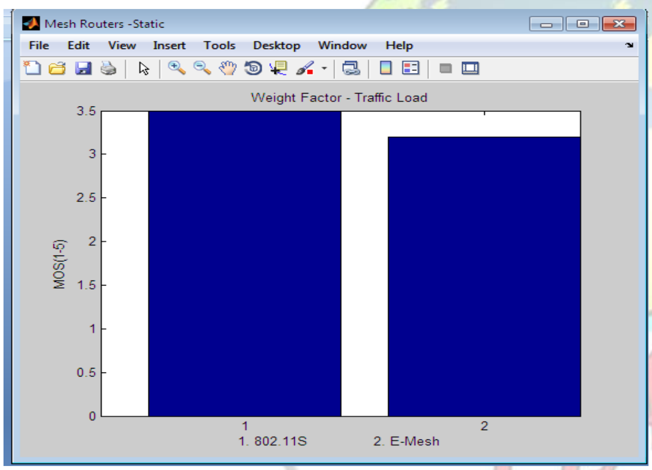

Fig 12 PSNR achieved with variable weights on mesh router distance when the routers are moving

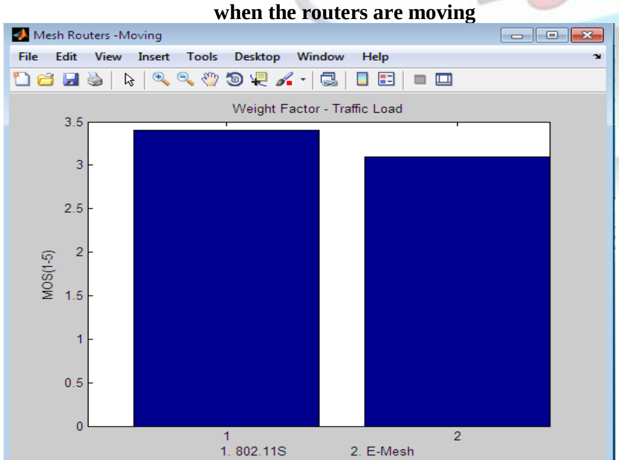

Fig13 MOS achieved with variable weights on traffic load when the routers are static

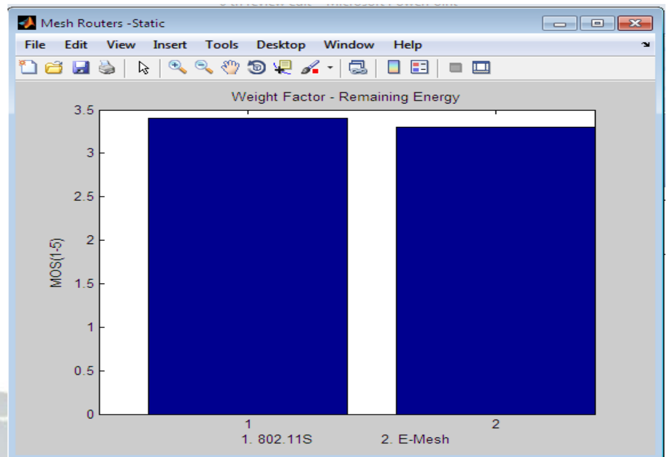

Fig 14 MOS achieved with variable weights on traffic load when the routers are moving

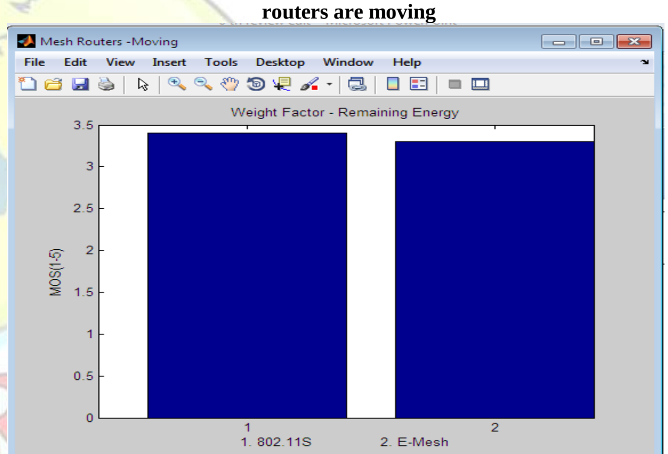

Fig 15 MOS achieved with variable weights on remaining energy when the routers are static

Fig MOS achieved with variable weights on remaining energy when the routers are moving On the other hand, the energy consumption rates of E-Mesh slightly increase along with the increase of *Wl*, which results in deviations of selecting the active neighboring mesh routers with higher traffic load during the routing process, regardless of the remaining battery energy on those routers. With the value of *Wl* set to 1.0, 2.0, 3.0 E-Mesh has achieved approximately 13.64%, 10.13%, 7.96% energy savings in comparison with the IEEE 802.11s routing protocol, respectively.

It is clear that with static mesh routers, E-Mesh achieves considerable energy savings in comparison with the IEEE 802.11s routing protocol, while maintaining roughly the same quality level with different values of *Wl*. The energy saving benefit of Mesh decreases along with the increase of the value of *Wl*, but still remains at a good level. When the increase of *Wl* exceeds a certain limit, the energy saving benefit does not overcome the quality decrease any more. The PSNR values of E-Mesh slightly decrease along with the increase of the value of *Wd*, but roughly remain at a s able level. With the value of *Wd* set to 1.0, 2.0, 3.0 and 4. , the transmission quality of E-Mesh remains roughly the same level in comparison with the IEEE 802.11s routing protocol, with approximately 0.4dB, 0.8dB, 1.2dB and 1.4dB decrease. It is clear that with static mesh routers, E-Mesh achieves better energy savings in comparison with the IEEE 802.11s routing protocol, which increases along with the increase of the value of *Wd*, while maintaining roughly the same transmission quality levels.

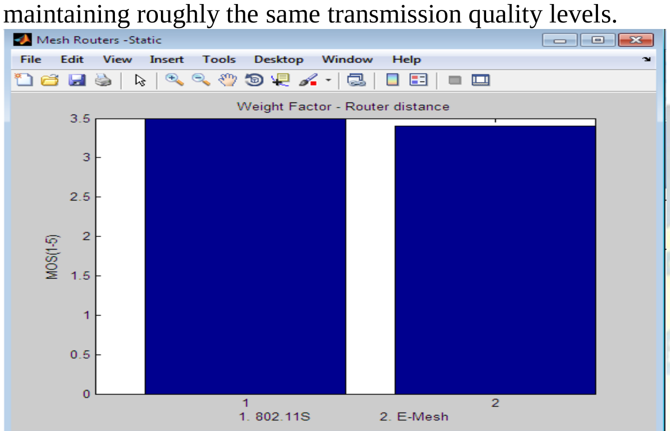

Fig 16 MOS achieved with variable weights on remaining energy when the routers are static

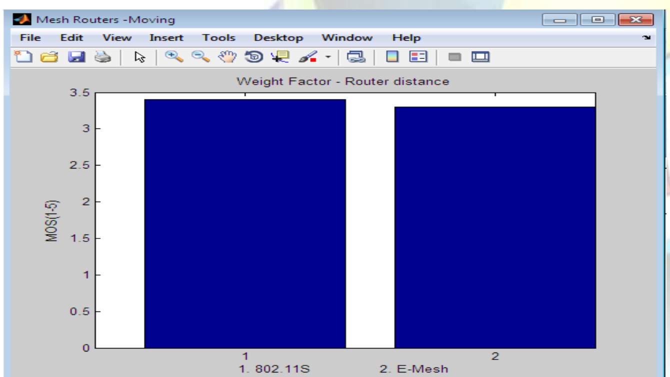

Fig 17 MOS achieved variable weights on mesh router distance when the routers are static

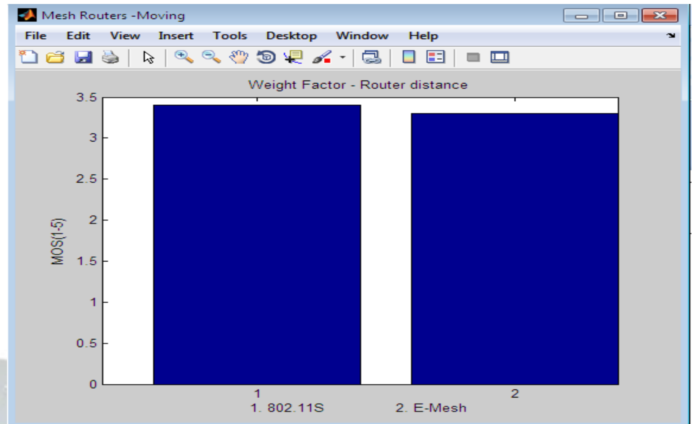

Fig 18 MOS achieved variable weights on mesh router distance when the routers are moving

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E-Mesh Utility function weight factor		PSNR(db) 802.11s		PSNR(db) E-Mesh	
		Static	Moving	Static	Moving
Traffic Load	1.0	29.53	28.53	27.66	27.86
	2.0	29.16	28.16	27.30	27.40
	3.0	28.02	27.02	26.66	26.98
Remaining Energy	1.0	29.53	28.53	29.66	29.66
	2.0	29.22	28.16	29.22	29.39
	3.0	28.02	27.02	28.01	27.47
Mesh Router Distance	1.0	29.53	28.53	27.88	24.65
	2.0	29.22	28.16	27.66	24.54
	3.0	28.02	27.02	26.45	24.12

Table 1 PSNR values with 802.11s and E-mesh

Table 2 MOS(1-5) values with 802.11s and E-mesh

E-MeshUtility function weight factor		MOS(1-5) 802.11s		MOS(1-5) E-Mesh	
		Static	Moving	Static	Moving
Traffic Load	1.0	3.51	3.43	3.49	3.31
	2.0	3.0	3.33	3.33	3.23
	3.0	3.49	3.28	3.23	3.15
Remaining Energy	1.0	3.49	3.43.	3.40	3.31
	2.0	3.43	3.21	3.37	3.06
	3.0	3.29	3.11	3.2	3.24
Mesh Router Distance	1.0	3.46	3.45	3.48	3.26
	2.0	3.43	3.32	3.36	3.22
	3.0	3.41	3.21	3.33	3.21

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VI. CONCLUSION AND FUTURE WORK

This paper presents an energy-aware network-layer routing algorithm E-Mesh with vector quantization based encryption for the purpose of energy saving, improving security and maintaining good application service quality levels for devices in wireless mesh networks. The performance analysis of E-Mesh with VQ based encryption was performed via simulations using MATLAB. Simulation models and prototypes for E-Mesh with VQ based encryption were developed and used for testing. E-Mesh with VQ based encryption was analyzed in terms of energy consumption rate, QoS and video-related transmission quality. Comparison was made between an IEEE 802.11s and E-Mesh with VQ based encryption with the same parameter settings. Performance analysis was investigated with the impact of various settings of the traffic load, remaining energy and mesh router distance weight factors in the E-Mesh utility function introduced. From the simulation results E-mesh with VQ based encryption provides better results than IEEE 802.11.

FUTURE WORK

Future work will include extension of E-Mesh to involve application layer and as part of the evaluation comparisons with existing adaptive energy aware solutions will be performed. E-Mesh's scalability issues will also be considered

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