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Energy Efficient Ambience Awake Routing with OpenFlow Approach

Hima Bindu Valiveti[1,*], SNV Ganesh[2], Budati Anil Kumar[1] and Dileep Kumar Yadav[3]

[1]Department of ECE, GRIET, Hyderabad, 500090, India
[2]Department of EEE, Avanthi Institute of Engineering and Technology, Visakhapatnam, 535006, India
[3]Department of CSE, Galgotia's University, Noida, 201310, India
[*]Corresponding Author: Hima Bindu Valiveti. Email: valivety.bindu@gmail.com
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Abstract: A major problem in networking has always been energy consumption. Battery life is one parameter which could help improve Energy Efficiency. Existing research on wireless networking stresses on reducing signaling messages or time required for data transfer for addressing energy consumption issues. Routing or Forwarding packets in a network between the network elements like routers, switches, wireless access points, etc., is complex in conventional networks. With the advent of Software Defined Networking (SDN) for 5G network architectures, the distributed networking has embarked onto centralized networking, wherein the SDN Controller is responsible for decision making. The controller pushes its decision onto the network elements with the help of a control plane protocol termed OpenFlow. Decentralized networks have been largely in use because of their ease in physical and logically setting the administrative hierarchies. The centralized controller deals with the policy funding and the protocols used for routing procedures are designated by the decentralized controller. Ambience Awake is a location centered routing protocol deployed in the 5G network architecture with OpenFlow model. The Ambience Awake mechanism relies on the power consumption of the network elements during the packet transmission for unicast and multicast scenarios. The signalling load and the routing overhead witnessed an improvement of 30% during the routing procedure. The proposed routing mechanism run on the top of the decentralized SDN controller proves to be 19.59% more efficient than the existing routing solutions.

Keywords: Energy efficiency; routing; smart networks; 5G; software defined networking; openflow

1 Introduction

The SDN principles have been in force from over a decade but the implementation of a complete framework and depicting the traffic streaming for various attachment procedures between the network entities availing the Open technologies has been minimal. Enhancing the networking and interfacing abilities, SDN creates an open platform by introducing a separation between the control plane and the data plane. SDN uses software to manage and manipulate the existing networks. All the functions are run as applications on the SDN controller. The existing Long Term Evolution/Evolved Packet Core (LTE/EPC) networks and the Unified Radio Access Network (RAN) are programmed with the help of Open interfaces to achieve scalable, flexible and have ability build an entire network that can be connected to the backhaul with the SDN controller as the intermediate system.

SDN when integrated with the Evolved Packet Core (EPC) guarantees to be cost efficient and proves to have reduced signaling overhead during traffic inflow and outflow. Choosing a shortest path for networking has always been a core criterion for traffic streaming whether it be signaling or data. The proliferation in the number of users upsurges the complexity of the network and thereby balancing the load becomes cumbersome [1–3].

Location Centered Routing Protocol (LCRP) uses the geographical location of the nodes for selecting the next set. It takes its motivation from the Greedy Perimeter [4] and face-2 [5] routing techniques. Unlike the approaches in literature, LCRP does not depend on any predefined arrangement of the nodes if the packet is being unicasted. According to the regular location oriented routing techniques, it is assumed that every single device is aware of its location by utilizing the global position services and the connecting devices in the neighborhood are updated by the Content Delivery Network (CDN) controller in the flow tables. The next hop-node is decided according to the flow tables. No concept of flooding happens in unicasting or multicasting like the traditional routing techniques as there is no tree formation. This saves on the computational time and eliminates redundancy. At the splitting junction of the device, replicas of packets are transmitted along all the connecting outlets. It is to be ensured that the length of the outlet path connecting destination devices is to be short and the hop-counts are to be minimal. Steiner tree is one kind of a tree that obliges to the desired hop-count criteria but LCRP is neither entirely based on the local awareness of the position of the node but not on hop-count nor is dependent on the shortest branching, which creates difficulty in directly using the Steiner tree distribution. The concept of LCRP is exploited for developing the current routing mechanism conserves energy based on the switching ON and OFF the used and unused OpenFlow (OF) switches respectively.

The current work emphasizes on implementing OF routing procedures for supporting cellular devices with the help of a decentralized framework based on Software Defined Networking principles [1,2]. The data packets will be routed only through the selected best route. OpenFlow mechanism is used to enhance the Routing Process. It configures and connects the network elements (switches, routers) to determine an optimal route for the traffic considered in the cloud based SDN [6]. Ambience Awake routing protocol finds the best path for reaching the destination on time without delay. When implemented for real-world applications like high speed vehicles, this protocol might help in achieving high throughput with lesser signaling loads [7,8].

The paper is organized as follows, Section 2 deals with the existing literature on software defined networks and routing mechanisms implemented in SDN and LTE network architectures. The section also specifies the motivation behind the current work, followed by the proposed Energy efficient Ambience Awake Routing mechanism in Section 3. Section 4 analyses and compares the performance of the proposed mechanism to that of existing routing solutions.

2 Related Work

Energy efficiency is a paradigm that has been a vital factor in the research arena from over a past decade. The inception of SDN principles with OpenFlow mechanisms has made routing simple and effective with least power consumption in the entities like network switches, OpenFlow switches, routers etc. Energy efficient routing mechanisms help serving more data and hence a larger community of consumers. A method to minimize the consumption of the system energy to effectively support Machine to Machine (M2M) devices is provided in [9] based on the correct configuration of the discontinuous reception cycle period. Instead, the authors in [10] suggest a group-based machine type communication method to support a large number of small-data transmissions with different Quality of Service (QoS) requirements. In particular, according to their QoS characteristics and specifications, the M2M devices are grouped into a cluster.

Clustering scheme is proposed by the authors to decrease the total energy consumption of MTC devices [11]. The plan considers a clustering approach with a low-energy guarantee from the group head. Consumption is curtailed by minimizing access between the software defined sensor networks and eNodeB modules. The authors Kharkongor et al. [12] stated the advantages and opportunities SDN routing offers and brings about a comparative analysis for forwarding the packets in the network based on Internet Protocol (IP) routing protocols. The authors also focused on the open challenges facing the industry and in the new network architectures. The open research options clearly state the deficit of a flow mechanism in the architectures built on SDN principles. The routing technique proposed in the current work attempts to mitigate the gaps in the existing SDN architectures.

Peng et al. proposed an Integrated SDN for routing mechanism by using OF mesh routers. The main aim of the paper was to increase the routing elements by using hybrid routing scheme. Hybrid Routing Forwarding Algorithm (HRFA) can be performed with conventional nodes that arrival of data streams can be forwarded by using Online Shortest Path First (OnSPF) routing protocol. Then SDN—Forward Elements (SDN-FE) described delineation of flows that can be performed with each flow and forwards the flow table. SDN-FE performance is based on Optimal route calculation for traffic: Link State Advertisement (LSA) process for topology, Feedback optimal path to the corresponding SDN-FEs: Once SDN-FE does not receive the reply message, it determines whether the current network link condition, Data forwarding and link state information monitors the network status based on the information and forwards the packets in optimal destination. However this process only supports small networks [13].

There is a need for a routing protocol that will require data transfer between heterogeneous devices. A routing protocol is suggested in this paper that will take into account the energy consumption of heterogeneous devices. In the network, an SDN controller is also implemented that functions as a centralized manager that provides a stable network by refusing access to greedy nodes present in the network.

3 Energy Efficient Ambience Awake Mechanism

The Energy Efficient Ambience Awake Mechanism is based on enhanced Greedy Multicast Forwarding (GMF) used to find the next set of hop nodes. The hop nodes are the neighboring nodes which have a feasibility of accepting the packet and routing via them. The flow table of the current node will contain the next destination, i.e., the next hop node to whom the packet has to be forwarded. Apparently the next hop node becomes the current node and the packet is routed. If the current wants to transmit to more than one destinations, then it multicasts the packet, i.e., splits the packet to the destined addresses in the flow table. Splitting is important as the packet has to diverge different ways to reach multiple destinations. OF devices like programmable routers and switches between the source and recipients replicate the data packets and then forward numerous duplicates wherever the path to destination nodes diverges [1,2]. Two distinct scenarios occur when a current node chooses the next hop nodes. GMF is used directly if the next hop-node is readily available else if there is no node left to forward the packet further, then the back tracing of the network is done by rounding the network to find the next hop node for packet forwarding. Once the packet transits back into the network, the GMF mechanism is engaged to find the route towards the destination. The next hop node ($h(S_N)$) is determined as given in Eq. (1).

'k' is said to be the next hop node which is the next forwarding node. These parameters are varied but seldom affect the other parameters, since the routing path is already selected. The first part in the equation gives the number of neighboring nodes to which the packets are transmitted and the second part is related to the computation of distance between the current node and the potential destination nodes. Distance between the two nodes is computed using the coordinate positions of the source and the destination nodes in the target area using Euclidean distance. A tree is not created initially during forwarding. However towards the end, all the forwarding paths themselves form a tree structure as depicted in Fig. 1 [1,2].

$$h(S_N) = \frac{\lambda\,|S_N|}{|N_k|} + \frac{(1-\lambda)\sum_{i\epsilon Z}\min_{m\epsilon S_N} dt(m,z)}{\sum_{i\epsilon Z} dt(k,z)} \quad (1)$$

where,

$\lambda \in [0, 1]$;

k—Next hop node,

N_K—Set of number of neighbours of k;

S_N—Set of number of subsets of N,

Z—Number of destination nodes,

dt(m, z) and dt(k, z) is a distance function measured between two nodes.

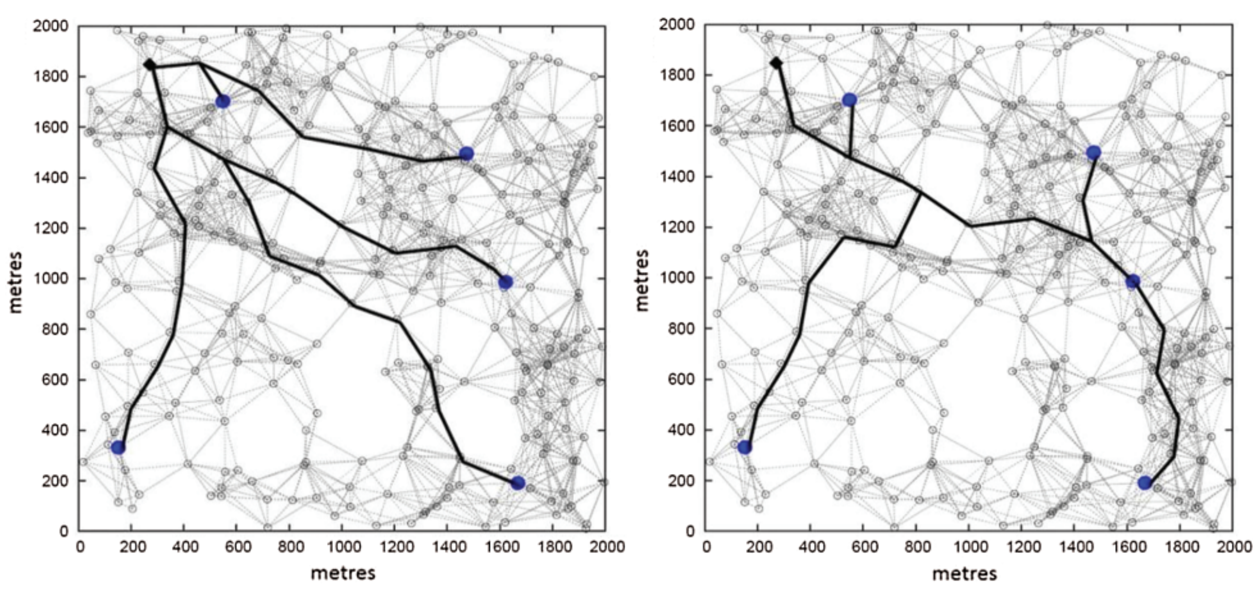

Figure 1: Packets split for forwarding ($\lambda = 0$) and ($\lambda = 1$)

As in the Fig. 1, the parameter λ decides the packet splitting. If $\lambda = 0$, packet splitting takes place at an early stage as shown in Fig. 1, else if λ is nearly equal to one, it depends on the user request for making decisions on packet splitting.

3.1 Degree of Connectivity

Unlike the conventional Position Based Multicasting (PBM), in the proposed work, only a set of nodes in the nearest geographical area are chosen as next hop nodes based on their Degree of Connectivity (DOC). The DOC is determined by the battery energy level and power computation of the device to increase the probability of connectivity and thereby avoid packet loss [14,15].

$$D_c \propto f(L_{batt}, \mathrm{P}_k) \tag{2}$$

where D_c is the DOC.

L_{batt} is the battery life and P_k is the minimum power requirement for an entity to communicate with its peer in the set of forwarding nodes

$$L_{batt} = \frac{Battery\ \ Capacity\ [mAh]}{Load\ \ current\ [mA]} \tag{3}$$

3.2 Power Computation of the Network Model Tree

Let's assume a source node, Src has k forwarding nodes. It is assumed that all the links consume a constant power for transmission as, $\mathrm{P_t}$, and $\mathrm{P_r}$ for receiving and for the computation as P_{comp}. To realize the power consumption P, compute the direct transmission power between Src and Dest as in Fig. 2. The battery lifetime of the node can be detected using its power consumption and decide on its degree of participation in the routing procedure. They are in indirect relation with each other [16].

$$\mathrm{P}_k = \mathrm{P}_{(Src \to Dest)} = (\mathrm{P_r} + \mathrm{P_t} + \mathrm{P}_{comp}) \times 2 \tag{4}$$

$$\mathrm{P}_{comp} = v \times f^2 \tag{5}$$

where v is the voltage in volts.

Figure 2: Power computation of the network model tree

And f is the number of instructions executed per second.

The forwarding nodes are chosen based on their energy consumption. The nodes with optimal degree of connectivity are chosen as the next node. The next node becomes the forwarding node and the procedure is repeated till the destination node/nodes are reached. The routing path is established based on the neighboring nodes and their energy states and hence the name Ambience Awake routing protocol. The energy consumption is reduced by making certain that the total number of links the packet traverses is minimized in terms of battery as well as devices power levels.

Fig. 3 illustrates the flow chart of the Ambience Awake routing protocol and its sequence process of routing. By using this protocol, we reduce delay and also improve the energy consumption of the network. Ambience Awake routing protocol is one of the best routing protocols for determining suitable route for transmission. The protocol serves better since the transmission of data can be performed without any delay and also packet loss is reduced.

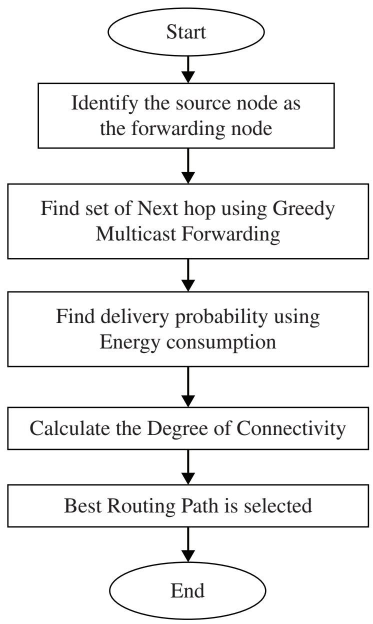

Figure 3: Flowchart for the routing process

4 Results and Discussion

The proposed Ambience Awake routing protocol incorporated in the decentralized network based on SDN principles is compared with that of the centralized network based (SoftNet) [17] on OF and the conventional LTE network [18]. For ease of simulation, the following assumptions are made:

i. The mobile device is always in connected mode and transits the networks to and fro in uniform rectilinear motion.
ii. All signaling messages are of unit length.
iii. The distance between the network controllers and the OF switch is set to 1 hop by supposing a dedicated line used for the OpenFlow signaling channel.
iv. The energy consumed by the links between nodes is the same.

The framework proposed by authors in [1,2] is implemented by using OMNeT++ simulation, which efficiently supports Graphical User Interface (GUI). Multiple eNodeBs, femto, pico and micro cells (small cells) with support from SDN server, CDN servers and several mobile users are randomly placed. The transmission rate of entities is about 100 Mbps. The source and the destination nodes are randomly distributed in an area of 2000∗2000 square metres. The proposed routing protocol is employed to obtain the best routing path between the source and the destination. The communication scenario depicts the uplink and the downlink between the user equipment and the internet as it includes the gateways and third parties in the communication set-up.

4.1 Performance Metrics

The following the metrics evaluated during the simulation procedure

i. **Overhead Signaling (OS):** Additional information to enable the communication between entities in the wireless networks
ii. **Average Route Length (ARL):** The number of hops required to create the best routing path
iii. **Packet Delivery Ratio (PDR):** The total number of packets lost during uplink or downlink procedures to total number of packets transmitted
iv. **Energy Efficiency (EE):** Total number of packets transmitted to the Total energy consumed. The higher the EE, the lower the energy consumption

4.2 Signaling Overhead

The signaling overhead is minimized by considering the overall energy consumption of the network and the energy efficient route prediction reduces the energy consumption incurred in the overall network. Fig. 4 depicts the same for the three architectures where the overhead for the proposed framework is improved by 30% when compared to the existing networks.

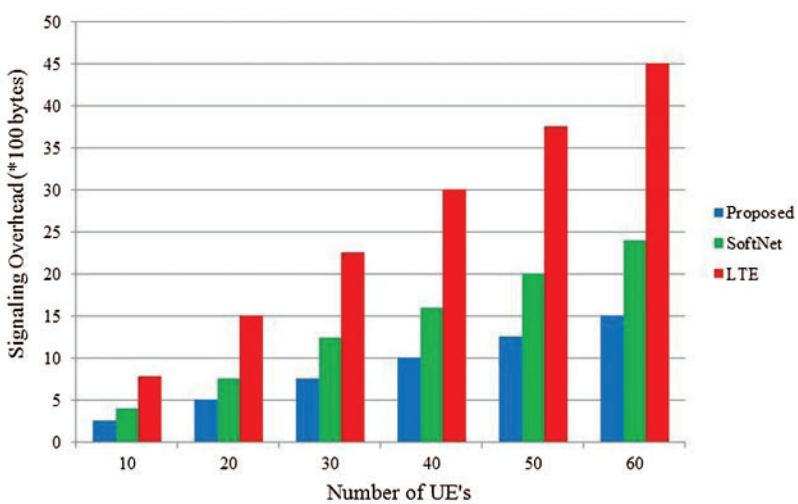

Figure 4: Overhead for signaling messages

4.3 Average Route Length

The ARL is measured in terms of physical hops as plotted in Fig. 5. The proposed Ambience Awake Routing algorithm acquires the forwarding nodes available and employs a second fold measure by acquiring the battery level of the nodes along with the energy consumed. It is evident that by the two-fold mechanism, the nodes that have optimal energy are counted for and the ones which do not acquire the degree of connectivity are avoided. Thereby the packet requires less number hops to cover the given number of nodes whether it be for unicast messages or multicast messages when compared to the position based multicast and unicast algorithms.

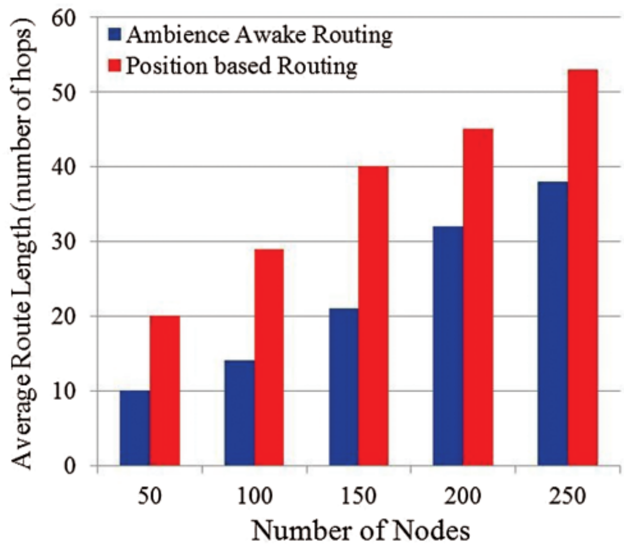

Figure 5: Average route length computation based on number of nodes

4.4 Packet Size and PDR and Energy Efficiency

The comparison results in Fig. 6 show an improvement in the packet loss over LTE and SoftNet networks using traditional optimized routing and OpenFlow routing schemes respectively. A high-quality difference in energy efficiency is observed due to efficient LCRP route discovery and data route confirmation considering the battery life. The degree of connectivity calculates the power required for the transmission of packets and decides on the best route. The OpenFlow switches are in OFF mode and only the switches intended to participate in the routing process are turned ON by verifying its status in the Flow table hence conserving more energy. The proposed framework with the new routing claims to be 19.59% more efficient than the OpenFlow routing. The degree of connectivity is determined by the battery energy level and power computation of the device to increase the probability of connectivity and thereby avoid packet loss as depicted in Fig. 6.

The most stimulating result can be seen in the Figs. 7 and 8, observing the energy performance in bits/Joule. The energy consumption of an entity depends on the product of the average rate of the power consumption of node (or OF switch) and the time of operation. The power consumed is that spent in the acquisition and processing the signals in addition to the transmitted power level and received power level. It includes the power consumed in the communication transceiver and also the quiescent power. For all three routing processes of the LTE and SDN architectures, Energy is conserved with the augmentation of packet size. For analyzing the routing solutions for OF and Ambience Awake procedures, the authors assume the minimum number of entities involved is 60. In comparision to all cases, the Energy Efficiency of the proposed Ambience Awake mechanism outrides the SoftNet routing technique by over two times and the LTE routing solution by five times as in Fig. 7.

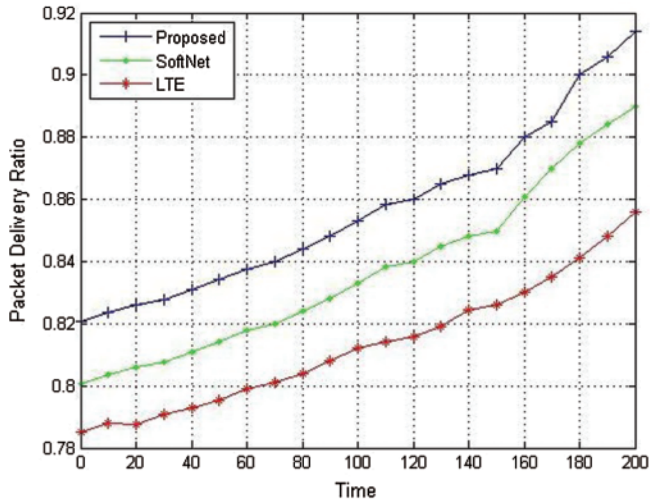

Figure 6: PDR variations with respect to simulation time

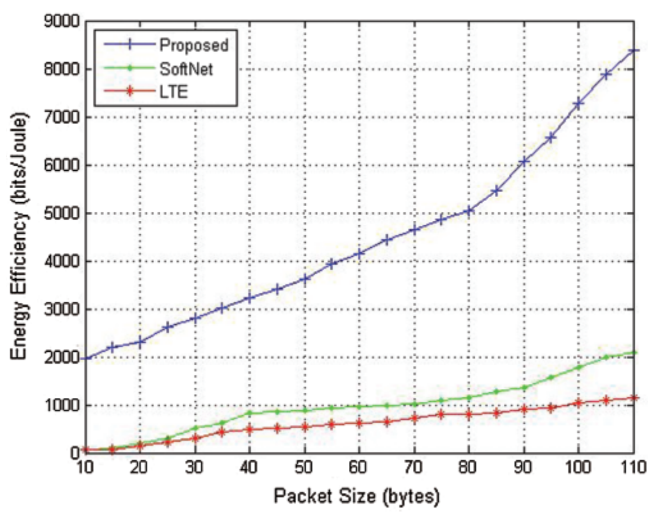

Figure 7: Energy efficiency for varying packet size (entities: 60)

When considering energy efficiency with the number of entities increasing between the source and destination with a packet size of 5 bytes each, it is observed that energy efficiency decreases greatly after passing through various switches or network devices as the power consumption increases but holds itself at a steady value after passing through certain number of nodes as in Fig. 8. This is because of the energy accumulated by the total number of entities the messages passes through equals to the maximum energy of the total number of entities in the network. The Ambience Awake routing algorithm exploits the position based routing principles and ensures that the neighboring nodes are selected by considering the least energy consuming entities resulting in a superlative mechanism in comparison to the existing techniques. Further incorporation of Optimization techniques will yield better results in utilization of lesser signaling load and delivering a better PDR.

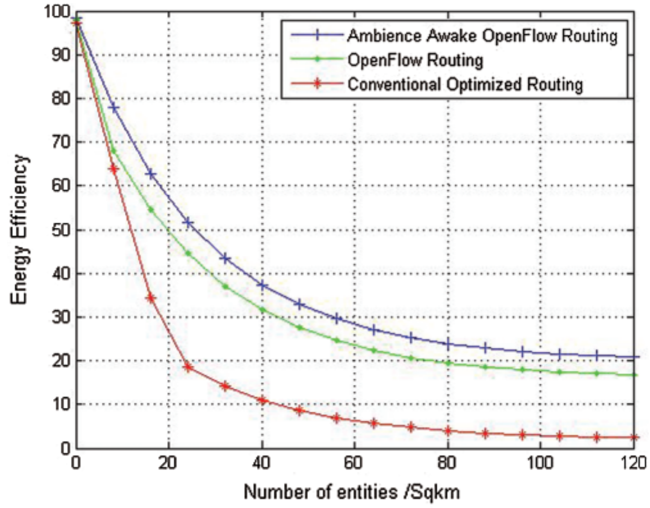

Figure 8: Comparative analysis of energy efficiency

5 Conclusion

The Ambience Awake routing devised for an SDN framework with decentralized server for managing mobility and gateway functions proves to be cost efficient when compared to the existing networks. The decentralized framework with the energy efficient algorithm, when compared to SoftNet and LTE networks, is formulated for choosing the best path of routing has decreased the signaling load of the network by 30%. The Routing overhead has been reduced by 30% after introducing a new routing technique based on SDN principles in the proposed framework. The new routing mechanism proposed with LCRP route discovery and data route confirmation considering the battery life of the nodes, claims to be 19.59% more energy efficient than the OpenFlow routing.

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