

End-to-end layered asynchronous scheduling scheme for energy aware QoS provision in asymmetrical wireless devices

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Abstract

In order to establish and maintain a Quality of Service (QoS) framework in wireless network, a major requirement is to prolong network lifetime, with simultaneous preservation of other major requirements like coverage, connectivity and adequate resources. In this work an approach is proposed which on a periodic basis it schedules the interfaces into active and inactive phases by using a layered state model and a tiered-based architecture. The model takes into account metrics like the signal strength and devices' capacity limitations, and encompasses them into the layered asynchronous scheduling scheme for end-to-end reliability and performance measures extraction. Each device schedules the next state (active, semi-sleep or sleep state) according to traffic and channel data rate measures, combined with the layered state scheme. Through the designed tiered architecture, and through experimental simulation, the proposed QoS energy-aware management scheme is thoroughly evaluated in order to meet the parameters' values where the optimal QoS and throughput response for each device/user is achieved.

1. Introduction

Transmission power control in mobile ad-hoc networks is a major issue for reliable end-to-end communication. Many researches have shown that the minimum transmission power that is required to keep the wireless network connected, achieves the optimal throughput performance in wireless devices. QoS is undoubtedly one of the central pieces of the overall packet network technologies either being supported by a wireless interface or by a wired. Particularly when hosting delay sensitive applications in such networks, the offered QoS plays the major role for the end-to-end accurate communication (either from user's perspective or network's perspective).

Traffic demands in mobile multi-purpose wireless networks can be classified in two broad categories, namely streaming (or delay sensitive) and elastic traffic, according to the corresponding QoS requirements. Streaming traffic corresponds to audio or video applications and requires low packet loss and delay/jitter, whereas the elastic traffic is considered to be a "don't care" packet chunks and usually corresponds to document transfers. Elastic traffic requires a low transfer rate and an inattentive file chunk completion time. Two types of network capabilities are needed to provide QoS in packet networks. First, to provide QoS, a packet network must be able to differentiate between classes of traffic so that the end users can treat one or more classes of traffic differently than others. Second, once the network differentiates between the traffic classes, it must then be able to treat these classes distinctly by providing resource assurance and service differentiation within the network. Indeed in infrastructureless wireless networks the survivability and the offered reliability are entirely based on the remaining energy of each node.

Effective Energy Conservation (EC) techniques enable higher QoS achievements. Thus, in order to provide QoS, effective energy conservation techniques should maintain a balance between the amount of energy a network conserves and the available resources (spare forwarding capacity) to sustain acceptable network performance and adequate QoS. Network partitioning problems may occur if network interfaces are turned off for prolonged time, resulting in unacceptable QoS provision for the end users. Hence, the energy conservation mechanism has to be closely collaborative with the incoming traffic characterization, with the routing protocol behavior used by nodes, and with the time constrained behavior of the node being in the idle state. All the above should be considered in the forwarding decision by nodes while maintaining the

packet forwarding mechanism and conserve radio resources -consisting of bandwidth and power.

Asymmetry is a significant factor for the QoS service provisions since it affects the end to end delay and the offered reliability, increasing at the same time the energy consumed. In this work classified/prioritized packets along with their characteristics and a layered model comprise an efficient way for saving power in wireless devices. The proposed approach is based on stream's characteristics with respect to different caching behavioral and storage-capacity characteristics along with the layered connectivity characteristics which take place for EC. These characteristics are modeled and through the designed tiered architecture and the estimated formula, the subsequent metrics of the scheme can be bounded and tuned into certain regulated values- as simulation results show. A performance comparison is done with respect to different traffic rates [1, 4, 5, 20] following a real time asymmetry channel. It is obvious that the self tuned behavioral caching enables significant energy conservation by using different delay metrics based entirely on promiscuous caching and on each channel's characteristics.

The organization of the paper is as follows: Section 2 discusses the related work that has been done on similar schemes which host energy-aware conservation mechanism and the conducted solutions proposed by each scheme. Section 3 then introduces the proposed delay sensitive stream-oriented on-demand scheme based on layered approach, and on how each node self-schedules the energy management that is suitable for hosting delay sensitive traffic. Through simulation, the QoS of the proposed scheme is evaluated and compared with the sleep history characterization and the possible affection on the overall idle or inactive/sleep duration in order to conserve energy. Also the provided scheme measures the impact of caching and storage-capacity measurements for energy aware QoS provision for asymmetrical wireless ad-hoc environments. Section 4 presents the evaluation of the proposed scheme and demonstrates the simulation results focusing on the behavioral characteristics of the scheme and the newly introduced metrics along with the system's response. Finally section 5 concludes with a summary of our contribution and suggestions for further research.

2. Related work

There is already a significant amount of research work, which addresses the routing layer [7-10] for enabling energy conservation as well as the MAC and physical layers [11-15] by using different approximation techniques. This work neither involves any layered end-to-end mechanism nor enables any routing layer involvement, but enables only collaboration among peers

which are using the architectural model of figure 1 as will be explained. The proposed mechanism takes action on a MAC and physical layers and on application layer where the behavioral on-demand promiscuous caching takes place in order to estimate the next node energy "idle" state or energy conservation delay. These mechanisms occur along with the estimated measures for storage and capacity characteristics of each node individually. Many protocols have been designed and use different mechanisms to reduce energy consumption; they are classified into two categories: active and passive protocols. Active techniques conserve energy by performing energy aware conscious operations, such as scheduling the transmission slots using a directional antenna [16], and energy-aware routing [17]. The passive techniques conserve energy by scheduling network interface devices to the sleep mode when a node is not currently taking part in any communication activity (packet forwarding) or being the end recipient node.

Some of the recently proposed protocols deal with MAC layer [7] issues and network layer [17] issues and some are based on topological and geographical information-based techniques (GAF) [18]. In [19] the goal is to turn off nodes without significantly diminishing the capacity or connectivity of the network. Also a traffic-load history determination in association with battery lifetime has been examined in [4]. In [4] the research is focused on load history characterization for each node, targeting the energy conservation for delay and non-delay sensitive services. The self-similarity of packet traffic characterization studied in [4] allows nodes to change their state depending entirely on their traffic history.

As a part of the already existing work done in [1, 3, 4] where a combination of history traffic scheme along with an association of the behavioral promiscuous caching characteristics and storage-capacity characteristics, this work proposes an architectural optimization of the previous frameworks by introducing the cross layered two-tier model to conserve energy. The model measures the validity and effectiveness of the new proposed middleware and controls the mobile interfaces by minimizing the energy consumed on any asymmetrically communicating wireless link. While some approaches based on overhearing or fading techniques do not actually address the association of EC (Energy Conservation) problem with any aspects of classified traffic, in this work this scenario is considered and examined. Parameters that an EC technique should be aware are user's behavior, data generation, traffic aggregation, means of network control, on-demand control mechanisms based on feedback and network connectivity as well as network connectivity formation factor. This work proposes a combined protocol which enables the self-configuration (actively measures the

network state in order to react to network dynamics) according to each node's state and based on the traffic history it evaluates and the new energy state of each node (active/idle/inactive) in a distributed and localized fashion. This scheme allows nodes to switch their states depending entirely on the architectural model and load/traffic history as it is discussed in the following section.

3. End-to-end layered asynchronous scheduling scheme for EC based on stream oriented delay sensitive approach

This section describes the approach using a layered asynchronous scheduling scheme for energy aware QoS provision in asymmetrical wireless devices. This mechanism associates the tier-based sleep state with the available capacity and caching characteristics of each node as well as the traffic and connectivity characteristics of each device which are asymmetrically connected¹ with any other device on the network. Overall this method targets the power saving on each device by enhancing the sleep time duration according to the mechanisms explained in the next section.

3.1. A layered model for scheduling energy states

A wireless node can operate in a transmission mode, receiving mode, idle or sleep modes in a network. Recent works have shown that energy consumption of being idle is dramatically higher compared to energy drain in sleep mode. Thus by scheduling the sleeping or active state of each node according to some parameters of the nodes, we may significantly reduce the energy consumption. An association of the sleep schedules and the state of each node according to some parameters like capacity and caching characteristics and measures, is not yet explored. The energy conservation mechanism has to be closely collaborative with the upper layer protocols used, to maintain the packet forwarding mechanism, in an error free mode. Upper layer protocols take into account the capacity measures and estimations as well as the remaining energy of each device. A best candidate solution must be cost-effective and adaptive, and should be able to keep abreast of any possible changes in the network in terms of load and failures. The above issues which combine the unpredictable movements of the users, along with each device's technical characteristics (like asymmetry) should be balanced. Based on all previous statements a new topological layering approach is being proposed. Figure 1 shows the main topological layering architecture that is proposed in order to enable

nodes to enter-if nodes satisfy the associated measures of the mechanism-to sleep state in order to conserve energy.

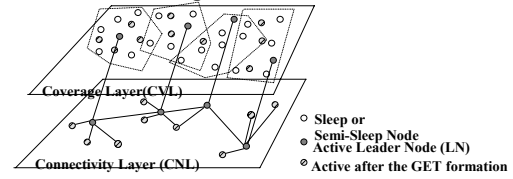


Figure 1: Architectural topology using a layered model in order to enable nodes to enter-upon mechanism-into sleep state in order to conserve energy.

In figure 1, LN is the Active Leader Node of every routing zone. In this scenario we have used the Zone Routing Protocol (ZRP) [16]. The active LN is chosen based on the remaining energy that an active LN candidate has. LN has the highest remaining energy of all nodes in the zone. Two layers have been proposed to expand the tier-based energy scheme: the above layer is the Coverage Layer (CVL), and the layer below is the Connectivity Layer (CNL). The CVL is the layer that contains the mapping of connectivity of the nodes in the hierarchical-based zone [2]-as explored in the ZRP. The CNL is the mapped layer of the existing CVL, which maps the exact connections according to the energy state of each node. This means that if a node is lying in the sleep state, there is no connectivity and therefore this node will not be mapped in to the CVL. However if a node is no longer transmitting or receiving-or even being an intermediate node for an end-to-end third party transmission, then it smoothly goes into the sleep state and another node should substitute the leaving node. This means that this node abandons the CNL and lie into the CVL. The CVL covers a pre-determined landscape. Therefore in the CVL there are some nodes which in order to conserve energy, change their status-from active to semi-sleep.

As known there are three basic states: The idle state semi-sleep state and sleep state. In the idle state, an interface can transmit (TX) or receive (RX) data at any time, but it consumes more energy due to the number of circuit elements that must be powered. The semi-sleep state stands for the optimal energy consumption of any radio device which is responsible only for hearing the neighbors with the transmitted "HELLO" messages, but without any reply back. On the other hand in the sleep mode, an interface can neither transmit nor receive, so it consumes significantly less energy. For transmitting or receiving, an interface must explicitly transition to the idle state, which requires both time and energy. The semi-sleep or idle state has the energy consumption in quite high levels, comparable to that of receiving and in an order of magnitude more than that of sleeping [1, 3, 2]. Thus in this work we discourage the nodes that lie in the semi-sleep state to have a prolonged period in this state, and we encourage these nodes to enter-if nodes

¹ Most researches focus on symmetric devices' characteristics. This work considers an asymmetric model.

satisfy the scheduling model- into the sleep state. This self-configured mechanism enables the collaboration among these layers (CVL and CNL). The entire model is primarily responsible for all parameterized mechanisms explained in the next section.

3.2. Layered asynchronous scheduling scheme and energy aware mechanisms in asymmetrical wireless devices

Layered topology architecture is being proposed for two main energy aware reasons: the simplicity in sorting out and forming the connectivity tree through Gradual Energy Tree-based (GET) configuration [3] via the CVL and for the simplicity in spanning out the users from a source to a destination through the CNL. Also the role of a traffic free layer is of main importance since we can prolong network lifetime as examined in [1, 3]. On the other hand the CNL will serve the traffic itself. However, as simulation results show, this does not affect neither the end-to-end nor the energy consumed by the hop-by-hop node in the path.

Figure 1 shows the CVL which hosts users that have no remaining energy or limited remaining energy in order to serve or participate in an end-to-end connection. The users that are set in the CNL are the users/devices which have adequate remaining energy according to the following:

$$P_{threshold} > \sum_{i=0}^n R_i \cdot d_i^r \quad (1)$$

In equation (1), P is the consumed power, r is the path loss exponent based on different channel models, d is the distance between to adjacent wireless nodes, R_i is the transmission rate of i link, and d_i^r is the distance of i -node to the next node-hop ($d_1 \neq d_2 \neq d_3 \neq d_4 \dots \neq d_n$ and where $2 < r < 4$). Thus if a sender wants to transmit a stream of data at rate R to a receiver, according to equation (1), the corresponding transmission power P should be at least equal $P_{threshold}$. Now, if a user lie in the CNL and the remaining energy of this user is at low levels or the remaining capacity is fluctuating at critical levels, then this user is temporarily transferred into the semi-sleep state for time T as follows:

$$T_{sleep}(N_{NSS}) = T_{N_A} \cdot (\sigma_i) \cdot \Delta t_{relative} \quad (2.1)$$

where T_{sleep} is the time duration the node N is allowed to sleep and to exist in the semi-sleep state, the σ_i is the *promiscuous caching* threshold parameter [introduced in 3]. When σ_i is minimized is considered as the optimal caching parameter for minimum energy consumption. The σ_i parameter is a function of $\bar{\delta}^{(m)}$ which is the promiscuous caching delay (duration in sec). The

associated caching eligibility of each node at any time during packet transfer is considered by using the following delay notation as indicated in [6]:

$$\bar{\delta}^{(m)} \approx \frac{\tau_0}{m} \log_2 i_P \quad (2.1.1)$$

where m is the number of identical sized chunks that the file is divided, i is the number of wireless peers in the path P and τ_0 is the amount of time taken to download the whole file, if downloaded from a single peer. Therefore a threshold for optimal caching (at any intermediate node) is chosen as:

$$\sigma_i = \frac{\sum_{i=0}^n R_i \cdot d_i}{\bar{\delta}^{(m)}}, \quad \sigma_i \cdot \bar{\delta}^{(m)} = \sum_{i=0}^n R_i \cdot d_i \quad (2.1.2)$$

where σ_i is the promiscuous caching threshold parameter or when minimized is considered as the optimal caching parameter for minimum energy consumption. The parameter $\bar{\delta}^{(m)}$ is the promiscuous caching delay (duration in sec) as examined separately in [3]. It should also be noted that the shadowing and fading characteristics are considered as in [3] where there has been an association of the data delay during data revocation from a node, with the node fading characteristics. $\Delta t_{relative}$ is the relative time that is affected by the following:

$$\Delta t_{relative} = [Max(\# of times CNL)] \cdot P_{remaining} \quad (2.2)$$

and $P_{remaining} = (1 - \frac{EnergyConsumed}{TotalEnergy})(\%)$ is the fraction

of the percentage of the remaining energy of the wireless device N . The number of times being in the CNL should be in the range of $0 < n < 2$, in order to avoid the saturation of the state of the node N to be in the same state-as shown in [2]. The number of times being in the CNL is calculated as follows: if the capacity was enough according to $C_{N \geq C_{threshold}}$ at a given time interval (t, T), then the Node N can securely enter the semi-sleep state in order to conserve energy if and only if it follows the optimality principle for the capacity, satisfying the:

$$P_{i_c} = P_i \cdot e^{e^{C_i}} \quad (3.1)$$

and

$$P_{i_c} = e^{e^{C_i}} \sum_{i=0}^n R_i \cdot d_i \quad (3.2)$$

where C_j is storage capacity of the node for which data packets from node i are requested. The equation 3.2 is optimal iff:

$P_{threshold} > \sum_{i=0}^n R_i \cdot d_i^r$ which means that according to

(3.2) and equation (1) then $P_i > P_{threshold}$ on a hyperexponential form.

Similarly with the equation (2.1) we then can define the time duration the node N that is allowed to be in the sleep state as:

$$T_{sleep}(N_{ss}) = TN_{NSS} \cdot (\sigma_{n(t)}) \cdot \Delta t_{relative} \quad (4)$$

where the T_{sleep} is the time duration the node N is allowed to sleep and to exist in the semi-sleep state, the σ_i is the *promiscuous caching* threshold parameter for the number of times being in the CNL in terms of time.

3.3. Energy aware effective throughput in asymmetrical wireless devices

In order to evaluate the lost packets we have first determined the ratio of transmitted and received blocks as follows:

$$RatioR = \frac{Received_Blocks}{Transmitted_Blocks} \quad (5.1)$$

Then the packet loss X is measured as follows:

$$Packet_{loss} = 1 - \left(\frac{Received_Blocks}{Transmitted_Blocks} \right) \quad (5.2)$$

where the effective throughput E_{ff} can be measured as follows:

$$EffectiveThroughput = E_{ff} = 1 - (Packet_{loss}) \cdot \left(\frac{PacketTraferredSize}{PacketTraferredTime} \right) \cdot \left(\frac{1}{Bandwidth} \right) \quad (5.3)$$

By using an exponential notation, we assume that power is reduced progressively [2, 4] with the remaining capacity on each node, which is evaluated by:

$$P_{i_c} = P_i \cdot e^{C \cdot E_{ff} i} \quad (6.1)$$

and

$$P_{i_c} = e^{C_i \cdot E_{ff}} \sum_{i=0}^n R_i \cdot d_i \quad (6.2)$$

where C is the total data density.

By using the power estimation above along with the caching and capacity measurements and characteristics we considered a further estimation of the stream oriented approach as introduced in [1]. Packets are parts of streams which comprise a file –with file chunk correlations (like multimedia audio and video streams). All packets have a time limit τ for reaching destination in a free erroneous mode as expressed in [11, 20] in order to arrive correctly at a specified destination. In our approach we also used the S_n notation and streaming

specification as used in [1]. S_n is considered as the streaming parameter for packets for a single application. These packets are marked as prioritized. The $S_{t-\tau, j}(S_1, S_2, S_3, \dots, S_n)$ is called streaming delay bound, where j is the number of the possible intermediate nodes, that any of the stream packets S_n might follow, and $S_{t-\tau, j}$ is the upper bound of the required time for correct reception of the stream, at the destination. The described scenario uses prioritized and non-prioritized packets (delay sensitive and “don’t care” packets [5]). These packets have a bounded time delay τ to reach any specified destination. In our scheme “don’t care” packets are further delayed onto intermediate nodes where prioritized packets are enforced to continue their “journey” to reach sooner their destination. Every packet delay is estimated by taking measures using the SODS mechanisms explored earlier along with the bounded capacity and the promiscuous caching threshold parameter [2, 3] as a function of the effective throughput E_{ff} . Simulation results show that there is an optimization in the offered throughput along with the energy that every node consumes. After examination this scheme saves energy while prolonging network’s lifetime and offers an efficient scheme for optimizing the throughput of the system. Additionally since this scheme considers the probability of a missing block, it therefore takes into account the packet loss probability. It offers an in-time arrival of data packets as well as overall throughput optimization. This methodology can significantly reduce the total consumed energy of all the terminals in the network. Finally the proposed scheme can provide upper protocol layer independency and can enable the usage of the cross-layer feedback control mechanism. This allows the lower level layers to adapt dynamically to changing network characteristics like capacity, energy and signal strength (distance).

4. Performance analysis through simulation and discussion

4.1. Specifications and routing protocol used

The proposed scenario is ensconced by the Zone Routing Protocol (ZRP) [16] which is a hybrid protocol, combining the reactive and proactive modes. The ZRP is considered advantageous because it allows to a certain node to accurately know its neighbors within a zone (in the CVL). These devices should be in a zone (in the CVL and supporting asymmetrical communication links) that could be accessible in a fixed number of hops. Since ZRP allow the absolute communication with neighbors, is considered less expensive, while neighbors contribute

in the routing process. Particularly, ZRP divides the network into several routing zones which are specified by a determined number of hops. This allows the routing protocol to be adjustable for different operational network conditions such as heavy traffic [13-15]. The specifications used for simulating our scheme are based theoretically on the WaveLAN PC/Card energy consumption characteristics found in the study by Feeney and Nilsson [22]. By using the WaveLAN PC/Card characteristics for the energy consumption we have approximate reference measures in our simulation scenario.

4.2. Performance results of the proposed scenario

The numerical results of the response of the proposed layered asynchronous scheduling scheme in combination with the performance measures are presented in this section. The simulation scenario took into account additional QoS measures like packet loss ratio, packet delay variation as well the promiscuous caching threshold parameter (σ_i). The promiscuous caching threshold parameter σ_i (or bounded optimal caching parameter for minimum energy consumption) plays a major role [3] and is considered along with the estimations of the values of P_i in terms of Φ_i (Φ is the fading channel characteristics parameter), for satisfying $Min(P_i, \Phi_i), Max(R_i), Min(\bar{\delta}^{(m)})$. The σ_i is estimated, taking into account many factors like end-to-end delay, hop-by-hop latency and power consumed over the delay and capacity measures. Some simulation experiments also were performed using different node capacities in order to evaluate the proposed scenario's response in contrast to node's required capacity for maintaining $Min(P_i, \Phi_i), Max(R_i), Min(\bar{\delta}^{(m)})$.

As previous researches cogently stated, the cached information destined for a proper node which is inactive should be stored in a node with higher residual energy. As simulation process shows, if nodes with higher level of residual energy are chosen in the path, then the network partitioning probability [4, 5] is further reduced. Therefore the cached process which takes place is chosen on a recursive path basis [1] in order to face discrepancies between packet delays and the storage capabilities of each node. The tree of Node Residual Energy (NRE) (expressed in [4, 6, and 15]) is created in order to enable an on demand caching and to assign the certain packets to a certain node of a specified path.

In the implementation of the described scenario, we used the spine model of [4] (based on C/Objective C programming language). Topology of a 'grid' based network was modeled according to the grid approach

described in [4]. In the simulation of the proposed scenario we used a two-dimensional network, consisting of 80 dense nodes (with no zone discrepancy restrictions). The topology changes dynamically as well as density and on a non-periodic basis (asynchronously as real time mobile users do). Each link (frequency channel) has max speed of 11Mb per sec (ideal speed), and the propagation path loss is the two-ray model without fading. We have also modeled on each node's communication protocol, an agent for generating and evaluating the data packets that are destined for a proper destination. The network traffic is modeled by generating constant bit rate (CBR) flows. Each source node transmits one 512-bytes (~4Kbits) packet. Packets are generated at every time step by following Pareto distribution as depicted in [4], and are destined for a random destination which is uniformly selected. Also it is assumed that each device/user has approximately 3GB of free storage capacity when entering the network. On a randomly chosen basis anyone of the users may send a data file (randomly chosen capacity contained) to any other user or users.

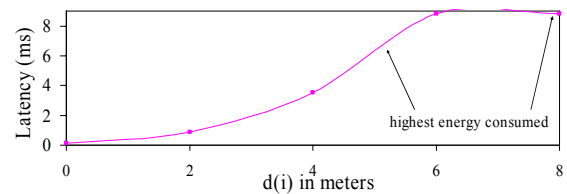


Figure 2: Hop by hop latency with the average distance $d(i)$ of each node in meters.

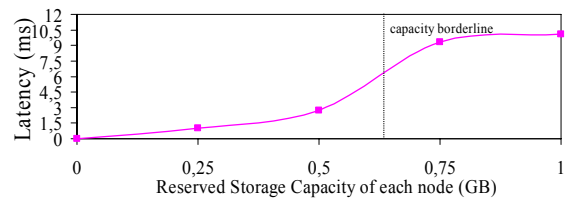


Figure 3.1: Hop by hop latency with the reserved storage capacity of each node in GB.

Figure 2 shows the hop by hop latency with the average distance $d(i)$ of each node in meters. Figure 2 depicts that close range devices are consuming less energy than long range devices. This means that the signal strength is significantly affects the energy consumed, for the close range devices (less<4m), experiencing the minimum possible latency in ms. Figure 3.1 shows the hop-by-hop latency with the reserved storage capacity of each node in GB. It can be easily spotted out that as much storage is reserved then the delay is significantly increased, affecting the thresholded values as figure 3.2 depicts. The capacity borderline in figure 3.1 is the maximum capacity limitation that is allowed in order to keep network lifetime in an

acceptable rate. Otherwise, by exceeding this limit, the network progressively will be flooded and EC will be negligible.

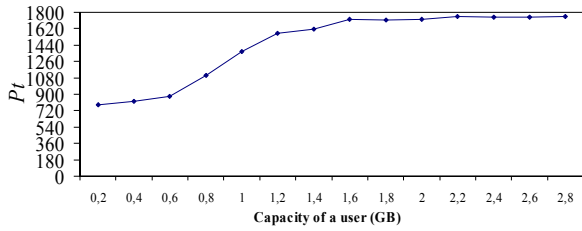


Figure 3.2: The estimated values of the energy threshold $P_{threshold}$ with the mean capacity of the user, at any time in the system.

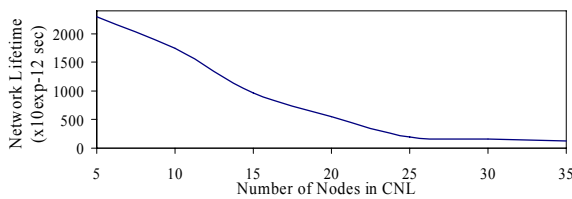


Figure 4: The network's lifetime with the number of nodes being in the CNL.

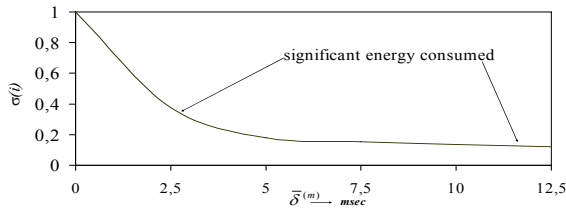


Figure 5: The caching threshold parameter with the average caching delay experienced by all the involved mobile peers in the end-to-end forwarding activity.

Figure 3.2 shows the estimated values of the energy threshold with the mean capacity of the user, at any time in the system. $P_{threshold}$ is considered very important in order to keep a track of the fluctuations of the energy since the bounded value of $P_{threshold}$ ensures the energy conservation by the system. Figure 4 shows the mean network lifetime with the number of nodes being in the CNL. Nodes that are set for a specified amount of time in the CNL are prone to saturated values, since as explained if the number of times a node enters into CNL is high, then the response of the system dramatically falls with the number of nodes and reducing at the same time the mean lifetime of the network.

Figure 5 shows the promiscuous caching threshold parameter with respect to the average caching delay experienced by all the involved mobile peers during the end-to-end forwarding activity. If a node -being an intermediate forwarder in a specified path- needs to

cache a specified capacity of data (based on equations (6.1, and 6.2), (2.1.1 and 2.1.2)), then if the average caching delay is kept in low ranges and the promiscuous caching threshold parameter at high, the energy threshold is bounded into the desired values. Additionally if fading channel intercalate with the above measures then the power of the radio waves decreases with the distance, and the power consumed is significantly higher.

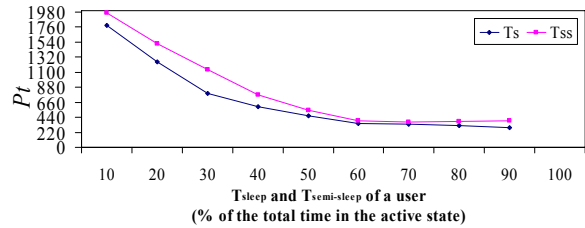


Figure 6: The estimated values of the energy threshold $P_{threshold}$ with the % of the sleep time duration and the % of the semi-sleep time duration of a user.

In figure 6 the estimated values of the energy threshold with the % of the sleep time duration and the % of the semi-sleep time duration of a user is presented. Both T_{ss} and T_s are kept in the bounded values for the $P_{threshold}$ if T_{ss} and T_s are estimated via the proposed model (equations (1) and (2.1 and 2.2)). It also comes out as an outcome that if nodes do not obey to equi-schedules for the sleep time duration, then the $P_{threshold}$ is satisfied and less energy is consumed.

Figure 7 shows the average throughput of the system with the number of nodes. It is obvious that for small number of nodes the average throughput is kept at a significant high level. On the contrary with this, if the number of nodes in the zone is increased (compared with the total number of nodes that exist/entered the network), then the average throughput is significantly reduced. In Figure 8 the bounded range of the achieved energy conservation in an end-to-end path is shown. Figure 8 shows that between the values 0.86 and 1.0 for the Φ fading channel characteristics parameter, the energy consumed is found to be at a desired level-as expected.

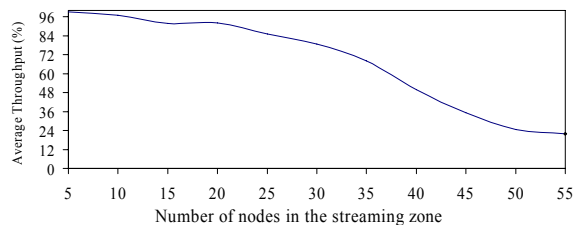


Figure 7: The average throughput of the system with the number of nodes in the streaming zone.

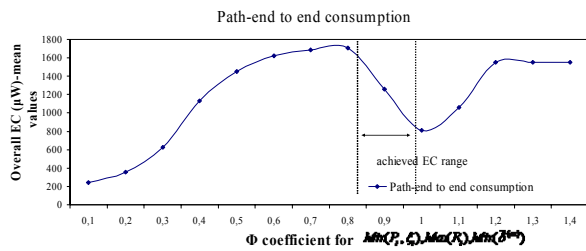


Figure 8: The bounded range of the achieved energy conservation in an end-to-end path (from a source to a destination).

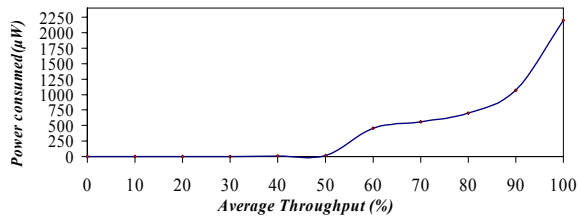


Figure 9.1: The power consumed with respect to the average throughput.

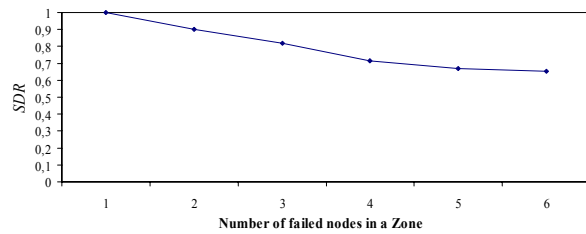


Figure 9.2: The successful packet delivery ratio (SDR) with the number of failed node in the zone at CVL.

Figure 9.1 shows the power consumed with respect to the average throughput. The proposed scheme can easily offer a throughput of 55% without consuming a significant amount of energy. It is also of considerable interest that even a greater than >80% throughput is offered with less than 1100 μ Watt being consumed. All measures were taken according to the scenario discussed earlier. In figure 9.2 the Successful packet Delivery Ratio (SDR) with the number of failed node in the zone at CVL is presented. The SDR metric, measures the exact number of packets which are sent and reached the destination at the other end (no matter how many hop counts come in between) over the total number of packets that are sent. It is shown that throughout simulation time the SDR is conserved at high levels particularly in the case of having even 6 failed nodes. This means that the transient state of the system can cope under these circumstances, facing the node failures by interexchanging the failed node in the CNL, with a node in the sleep or semi-sleep state in the CVL.

5. Conclusions and further research

In this work, we have proposed an association for controlling the power consumption parameters into a bounded limit and within a range of bounded values. Caching threshold parameter is introduced in order to bound and mitigate the mobility, storage/capacity and traffic characteristics with the overall energy consumed by the system. Also the effective throughput is taken into account with the above, for the estimation of the energy consumed and the effective measure of the remaining capacity of the asymmetrically communicating links, connectivity, channel quality and fading characteristics, and channel's available bandwidth. Experimental simulation results show that the system under certain conditions offers the optimal energy conservation. The scheme also considers an association with the traffic density, storage measures and the impact of caching.

We are currently working towards an extension of this framework which takes into account other factors like network formation/partitioning problems due to excessively saturated values of the number of times a node should be in the CNL. This scenario is currently being planned to be applied for experimental purposes in HiperLAN/1-based mobility scenario.

6. References

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