Handling Delay Sensitive Contents using Adaptive Traffic-based Control Method for Minimizing Energy Consumption in Wireless Devices

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Abstract

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. By prolonging the network lifetime the overall performance substantially increases. Particularly when delay sensitive packets/multimedia streams are sent from a wireless device to another, the end to end communication must offer sufficient reliability and integrity. This paper describes a quantitative approach based on incoming traffic flow which bounds an asynchronous operation where each node evaluates dissimilar sleep-wake schedules. This scheme is entirely based on each node's incoming sleep-history traffic. Different sleep-wake schedules are continuously influenced for each node by packets and multimedia streams which are uniformly injected into the network. Simulation study is carried out for the energy conservation evaluation of the proposed model taking into account a number of metrics and estimation of the effects of incrementing the sleep time duration to conserve energy. Results show that the proposed method could be applied to infrastructureless networks to provide reliability for multimedia and delay sensitive packets without a significant increase in the power consumption.

1. Introduction

Nowadays the ubiquitous presence of mobile phones and PDAs equipped with close range radio connectivity like Bluetooth [12] and WLAN create a fertile environment for multimedia applications. Wireless devices are a collection of wireless nodes that communicate over radio. This set of mobile nodes does not need any infrastructure. These kinds of networks are very flexible and suitable for several situations and applications allowing an infrastructureless network without any preinstalled components. Every node acts as a router and has limited transmission range while the communication traffic has to be relayed over several intermediate nodes (multi-hop) to enable the communication from a source to a destination.

Nodes in wireless networks typically rely on their battery energy. In this paper, an Adaptive Energy Conservation (ADEC) protocol is examined that turns off nodes interfaces to save power of each node and maximize the network lifetime. As known in a terminal the latency, connectivity, energy and memory are the essential elements of today's mobile environments whose performance may be significantly improved by caching techniques. The protocol for dynamic caching and energy conservation was first proposed in [17]. This protocol uses traffic patterns for the thorough examination of network behavior. Adaptively ADEC scheme assigns a variable sleeping time based on traffic that each node "accepts" throughout the sleep time duration based on a self-similarity nature of traffic. Therefore ADEC by using dynamic caching manipulates network state in a distributed form and actively controls each node's sleeping duration, to minimize the energy cost of peer-to-peer communication among mobile terminals. In addition this method provides a way to guarantee the buffering of data and a way to overcome the loss of packet information. Finally this model could be applied to ad-hoc networks with any underlining routing protocol support to provide independency as well as "fair" collaboration among energy conservation mechanism and routing protocol.

The organization of the paper is as follows: Section 2 discusses the related work that has been done on

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energy conservation (EC) featuring out the basic energy conservation principles and conducted solutions by different schemes. Section 3 then introduces the proposed Adaptive Dynamic Caching Energy Conservation (ADCEC) for delay sensitive packets, followed by Section 4 which provides the evaluation and simulation results of the proposed scheme in contrast to the energy consumption associated with Adaptive Dynamic Caching. Finally, Section 5 concludes with a summary of our contribution and suggestions further research.

RADIO INTERFACE IEEE 802.11 Interfaces (2.4GHz)	TRANSMIT	RECEIVE	IDLE	SLEEP MODE	Mbps
Lucent Silver	1.3 W	0.90 W	0.74 W	.048 W	11
Lucent Bronze	1.3 W	.97W	.84 W	.066 W	2

Table 1: The degree of power consumption and Digital Radio Power States (DRPS).

2. Related work

Minimizing energy consumption and maximizing the system lifetime has been one of the major design goals for wireless networks. On the one hand, many wireless device manufacturers have been striving for low power consumption in their products [2], exploring and discussing their low power transceiver architectures and low power signal processing systems. On the other hand quite a lot of protocols have been designed and use different mechanisms to reduce energy consumption, that can be classified into two categories: Active and passive protocols. Active techniques conserve energy by performing energy conscious operations, such as transmission scheduling using a directional antenna [6], and energy-aware routing [4-5]. On the other hand passive techniques conserve energy by scheduling network interface devices to the sleep mode when a node is not currently taking part in communication activity.

Many different protocols were designed taking into account separately aspects dealing with MAC layer [7] network layer [3-5], topological and geographical information-based techniques (GAF) [8]. In [8] the entire network is divided into small virtual pieces (grids) and this area as recognizable by geographical information allows only one node to be active in the grid while the other nodes turn off their interfaces to conserve energy. In [9] the goal is to turn off nodes without significantly diminishing the capacity or connectivity of the network. The connectivity and forwarding capability as stated in [9], is maintained by keeping the nodes that constitute a backbone infrastructure in active mode, and switching off the other. However nodes' participation in network forwarding activity [1] is adaptively adjusted, based on their buttery remaining energy. In Table 1 the rates of consumption are presented for some commercial transceivers [1-5] and their DRPS. It is easily recognizable from different radio card samples that the rate of consumption in the "receiving" state is more than 50% of that consumed in "transmitting" state. There is importance to appropriately determine when and at what power level a mobile host should attempt transmission or retransmission of packets.

A traffic-load history determination in association with battery lifetime has only been examined in [17]. This work the overall 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 [14, 15] enables us to examine such scenario. The proposed adaptive method allows to nodes to change their state depending entirely on their traffic history under various conditions as discussed in the following section.

3. Adaptive Dynamic Caching Energy Conservation (ADCEC) for Prioritized Traffic

This section describes the ADCEC method, which bounds a partially asynchronous operation where each node evaluates dissimilar sleep-wake schedules/states based on each node's incoming sleep-history traffic.

3.1 A cooperative caching scheme

The efficient message passing in a distributed decision system plays a major role for the offered QoS parameters as well as for the power consumption. Energy conservation mechanism has to be closely collaborative with the routing protocol used for the proper/acceptable behavior of nodes being in idle state and maintain the packet forwarding mechanism. But routing packets in wired/wireless communication network needs essentially a dynamic approach due to the stochastic nature of data traffic. An on demand cost-effective, adaptive solution-finding algorithm is in principle more attractive because it can keep abreast of any possible changes within network load and failures due to energy deficiency. Particularly for wireless devices/networks where nodes cooperatively form a network independently of any fixed base station infrastructure (usually infrastructureless). On the other hand in dynamic caching-oriented methods there are some trade-offs that have to be taken into account, such as generated overhead in message passing for delay sensitive services, network utilization, simplicity for the implementation on the wireless environment etc.

In Adaptive Dynamic Caching messages are manipulated using a specific routing protocol as will be described in the next section. Packets for routing and control purposes are contributing any time in the network for informing the neighboring nodes or all nodes in hops (route) for residual energy. Roughly speaking one of the most important task in dynamic caching is whether a node will decide to send an acknowledgement message (ACK) to neighboring nodes or in a zone (based on the routing protocol used) for informing about the current state and the state of the next time step. If a packet needs to be sent from a source to a destination some intermediate nodes or even the destination might be in a sleep state. For intermediate nodes packets are routed via another optimal path depending on the routing protocol used. A question arises for the decision of which node will 'cache' the information for the destination node in the route (hop-by-hop basis) when the destination node or any intermediate node "lie" in the sleep mode. As known, in the sleep state node's interface can neither transmit nor receive, so it consumes energy. As a result the destined information for a proper node in sleep mode after a "timeout" will be lost.

In order to achieve an adaptive solution for this issue acknowledgement packets ACKs are sent to each neighbor in the zone (as in ZRP [6, 16] which will be explained in the next section). ACK packets are sent for informing each node about the state of the candidate node for sleep state. The mechanism used selects the previously followed node in the route (neighbor to node in the sleep mode) to cache the packets destined for the node with turned off interfaces (sleep).

This is shown in Figure 1 where packet is destined for wireless device (Node 10) from node 1. Suddenly (for triggering or energy consumption reasons) node enters into the sleep mode in order to achieve energy conservation. The time instant is not suitable since all packets destined for Node 10 will be lost (partially or in total depending on sleep time). ADCEC method enables the packets to be "cached" in the previous hop node (Node 7) from Node 10 and forwards the packets destined for Node 10 when Node 10 enters the active state. Therefore no information will be lost since it will be held in Node's 7 buffer (storage unit). Additionally the main difference from [3-9] is the adaptivity. The adaptivity occurs for the incoming traffic of the destined node [13-15]. In Figure 1 it is considered that for node N=10 the traffic is $T_{C(t),N}$ where T is the incoming traffic, and *C(t),N* is the capacity in the certain time interval t for node N. Node 7 caches the packets for Node 10 thus increasing the storage unit for Node 10 in Node 7's unit. This corresponds to $C_{s,i}(t)$ where i is the destination node and t is the buffering node (a hop before destination). It must be also pointed out that in figure 1, node's 5 destined information could be cached also in node 3. Routing decision blocks this option since there are no memory limitations for node 7. Procedural packets PROC continuously inform for route discovery the 'route neighboring' nodes, as well as for TTL (applicable for delay sensitive services where if necessary other optimal route should be activated), residual energy, and history of all visited nodes. Furthermore PROC packets pursue one important operation: they determine whether a node can enter with safety to sleep state i.e. if there is forwarding activity in the proper time which in turn depends on the routing protocol[1], idle time and residual battery energy.

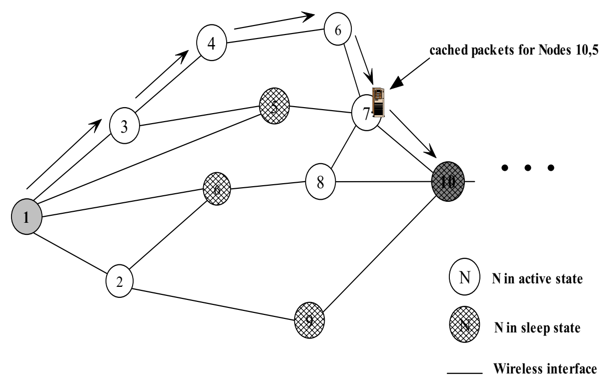

Figure 1: Wireless devices connectivity and different activity states.

The main issue for conserving energy is to identify and associate the cached packets with the next sleeping time of the intended node. This requires the adaptivity of the cached capacity (stored packets- traffic during sleep time for Node 10) with the next-following duration of sleep time of node 10. This sleeping time will be proportionally influenced with the cached capacity in the time distance which is $t_i(t-t_D)$, where t_D represents the equally spaced/triggered time slots. A thorough explanation of this principle is conducted in the following section.

3.2 Operations for adaptive energy conservation for delay sensitive transmissions

When heavy load exists in wireless devices, the commonly used and known periodic sleep/listen scheme does not benefit for efficient energy conservation. The evaluation and design of energy efficient communication protocols therefore requires practical understanding of the energy consumption behavior of the underlying network interface. The main

[1] The routing protocol used in the implementation is ZRP [16].

aspect for interface to consume energy is basically the mode it does operate. As known there are two basic states: The idle state and sleep state. In the idle state, an interface can transmit or receive data at any time, but it consumes more energy due to the number of circuit elements that must be powered. 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 idle energy consumption is quite high, comparable to that of receiving and in an order of magnitude more than that of sleeping [7-9], (see Table 1).

In the previous section a simple scheme is described for caching the data packets destined for a proper node. The capacity of the cached data corresponds to time duration $t_i(t - t_D)$ for the next sleep duration of the destination node. Sleeping time for destination node is high enough when the node in the previous time sleeping slot (that is $t_i(t - t_{D(\tau-1)})$) did not receive any packets. Hence it stands that for time *τ*:

$$T_{C(\tau),N} < T_{C(\tau-1),N} \text{ then } t_{D(\tau+1)} \geq t_{D(\tau)} \quad (1)$$

for node *N*, and *τ=1,2,3..m*.

Thus if t_D is high then the next sleep duration of node N will be in turn higher than the previous one (due to inactivity of the node in the $t_{D(\tau-1)}$). In this way each node evaluates dissimilar sleep and active states based entirely on each node's incoming sleep-history traffic (in-sleep history). This principle is shown in Figure 2.

Sleep time duration can be measured using the following expressions:

$$\Pi_{MM} = \left(1 - \frac{cached\_MM\_packs}{Total\_MM\_packs\_destined\_for\_D}\right)^{T \cdot N} \quad (2.1)$$

$$S(t_{new})_D = S(t)_{D(\tau-1)} - S(t)_{D(\tau-1)} \cdot \left[\frac{Packs\_cached}{Total\_packets\_destined\_for\_D}\right] \quad (2.2)$$

where Π_{MM} is the streaming factor based on each multimedia stream, T is the time that passed since the beginning of MM packet transmission from source node, and N is the number of hops in the path from source node to destination. $S(t_{new})_D$ stands for the new time duration[2] depending on the traffic history of the route destined for D, and $S(t)_{D(\tau-1)}$ is the previous time step (slot) duration. Then the new sleep time duration for the destination node is evaluated in:

$$S(t_{new})_D = S(t_{new})_{D(\tau-1)} \cdot \Pi_{MM} \quad (3)$$

[2] New time duration cannot exceed twice the corresponding value.

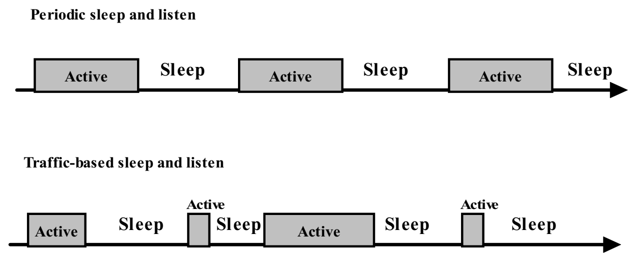

Figure 2: Different duration of sleep/wake schedules, based on node's incoming sleep-history traffic.

Capacities and durations are *normalized* in order to overcome *latencies* problems. Only *latency* (usually for delay sensitive services) can "disturb" sleep period by placing a limit on the sleep time duration of the nodes. PROC packets are purely responsible for informing the node for any limitations. If a node does not receive any packets for a long period due to the stochastic nature of incoming traffic, the sleep time will increase at an unneeded grade. Thus PROC packets by using a specified field PROC_tLIM place a limit on the sleep time of the nodes to avoid increased latency which results in network partitioning. Also in order to prevent a large number of nodes to enter into the sleep state and at the same time avoid network partition, we set a maximum number of nodes that are allowed to be in the sleep state (entirely based on the total number of nodes of a non-partitioned network).

For each node there are three states: the "active", the "sleep" and the "wait to sleep" or "listening" state. Figure 3 shows the state transition diagram of each node. In the active state node's interface can transmit or receive data at any time but consume more energy. If incoming traffic is continuously coming/destined for the node, it keeps remain in the active state. This "loop" is not energy efficient and it breaks if traffic is reduced. In this case node changes into listening mode for a while. Then if traffic is further reducing, after $t_{D(\tau)}$ with no incoming traffic for the time duration $t_{D(\tau-1)}$ node enters into the sleep mode. Sleep mode is only corrupted and "violently" node enters the active state if there are serious latency limitations and/or sleep period expires.

Roughly speaking while traffic is not uniformly distributed, it does not allow the equally spaced sleeping duration to be efficient for conserving energy. During initialization period node from active state enters the sleep state by measuring the traffic and setting a time T after activation. Traffic transits each node's state through the traffic history of each node during $t_{D(\tau-\Lambda)}$, where Λ is the time duration for the previous slot of that node for which data is cached.

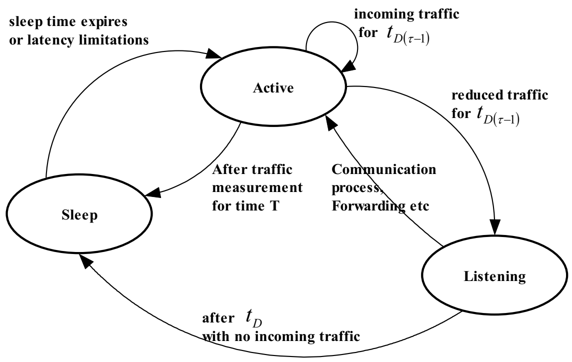

Figure 3: Node operation cycle as a state transition diagram.

Figure 4 shows the state-time scheduling for a single multimedia stream. At S_0 (initial state) node sends route request (r_{REQ}[3]) to a candidate next hop node. In turn the candidate node answers to source node and source node decides whether the route is suitable. MM packets have transmission expiration time and a TTL tag. At S_0 state, node knows at any time the candidate next hop node N_{i+1} by sending continuously r_{REQ}. Then the source node sends back to N_{i+1} the number of MM packets that are destined for N_{i+d} node (d is the number of hops to the κ destination, $\kappa = i + d$). N_{i+1} node then answers about its status and the transmission(s) of MM packet(s) starts. This loop continuously occurs at any neighboring node of N_i until the stream will 'abandon' N_i. At S_3 the prioritized MM packets are either routed to destination node or cached to an intermediate node N_{i+d-1} [17]. The difference time distance $\Delta(T_{MM}^{D})$ between the states S_3 and R_{rx} is crucial for delay sensitive services. However if the transmission delay and $\Delta(T_{MM}^{D})$ is in the predetermined time interval, the stream is not corrupted. Otherwise if MM packets fail to reach their destination in the specified time interval, destination node rejects these packets and retransmission of the stream must take place. Many packet retransmissions mean substantial end-to-end delay and crucial energy consumption.

This cooperative caching method among nodes for energy consumption bounds many aspects for mobile environments hosting real time multimedia applications. Experimental examination is performed for the above scenario and results are presented in the following section.

[3] Calculates the route request and the end-to-end delay of the requested path.

4. Simulation experiments and discussion

The design and evaluation of energy efficient communication protocols requires practical understanding of the energy consumption behavior of the underlying network interface. To demonstrate the methodology discussed in this paper, we performed exhaustive discrete time simulations of the proposed scenario under several different conditions.

4.1 Routing protocol used

One basic issue is the selection of the routing protocol that should be used in order to cooperate with the described scenario. Considering the need of bandwidth and the limited battery power for wireless devices, it is necessary to apply efficient routing algorithms to create, maintain and repair paths with least possible overhead production [2]. There are two classes of routing protocol: proactive and reactive. In proactive or table-driven protocols the routes are maintained for all possible destinations continuously-periodically, even if routes will not be actually used. The generated overhead from route maintenance cause significant reduction of network performance, increase in end-to-end delays and delay variations. Reactive or on-demand protocols on the other hand, create and maintain routes only when they are needed.

In the implementation of the proposed scenario the Zone Routing Protocol (ZRP) [6, 16] is used. ZRP is a hybrid protocol that combines the reactive and proactive modes. The ZRP is considered advantageous because allows to a certain node to accurately know the neighbors of any mobile terminal within a zone. These devices should be in zone 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 specifying a determined number of hops. This allows the routing protocol to be adjustable for different operational network conditions such as heavy traffic [13-15].

4.2 Simulation results of the proposed scenario

To emulate the scenario described earlier, the need of a possible realistic environment must be achieved. In this section, we present some experimental and simulation results for performance evaluation and energy conservation offered by our scheme. The power could be measured by monitoring the three basic metrics-energy components: (i) *transmission* power required to send a packet, (ii) *reception* power required to receive or listen to a packet, and (iii) *idle* power required to stay in at the active state (awake) in contrast with sleep time duration that follows. Transmission power includes both the power required to drive the circuit and the transmission energy from the antenna [1, 2]. Therefore, the energy consumed by any mobile terminal for sending, receiving or discarding a message is given by the linear equation[4] [1] $Energy = m \cdot size + \beta$; where *size* is the message size, and m denotes the incremental energy cost associated with the message and β a fixed cost of each operation.

The energy consumption model used in the simulation, for the calculation of the amount of energy consumed, is based theoretically on the WaveLAN PC/Card energy consumption characteristics found in study by Feeney and Nilsson [1].

Two sets of experiments were performed. One set deals with the caching concept and the grade of contribution in conserving energy, and the second deals with the energy conserved under significant traffic and network partition limitations and the latency issues that arise. As mentioned the caching capacity of each node could be unlimited while nowadays memory becomes cheaper and cheaper. If node has unlimited capacity then traffic will reach a huge load destined for a node at the sleep state. This will result in delay problems. Thus taking into account this issue, in this paper we evaluated two different types of caching capacity:

(i) Unlimited capacity
(ii) Limited capacity for each node as 64KB, 128 KB, 256 KB, 512 KB, 1 MB, 2MB.

An issue that has to be taken into account is whether the cached information destined for a proper node could be stored in a node with higher residual energy. As shown in simulation process if nodes with higher level of residual energy are chosen in the path then the network partitioning probability is further reduced. For this reason cached information is chosen on a recursive path basis, where source node while having the path tries to find the node with the higher residual energy in order to assign the caching process.

Another issue that arises for wireless devices is the dynamically changing topology of the network. If a caching information process takes place and a node or some nodes in the path will change their state into sleep mode then the path simultaneously changes having at least the 'caching' node within the new path. If this enterprise is impossible due to sudden network partitioning then before network splits, the node which caches the information forwards the cached information to destination which violently enters the active state.

[4] Linear regression is used to test the model and find values for m and β.

In simulation was used a two-dimensional network, consisting of 25 nodes with each link (frequency channel) having max speed reaching 2Mb per sec. The propagation path loss is the two-ray model without fading. The network traffic is modeled by generating constant bit rate (CBR) flows. Packets generated at every time step by following Pareto distribution (2) as depicted in [13-15], destined for a random destination uniformly selected.

Figure 4 shows the incoming flow-traffic (in measured packets) at a random node using the Pareto distribution for 500s duration. Roughly speaking the load generated by one source is mean size of a packet train divided over mean size of packet train and mean size of inter-train gap or it is the mean size of ON period over mean size of ON and OFF periods.

Additionally we have modeled in each node an agent which evaluates the information destined for a proper destination. In this way we have at any time measures of the information destined for each node (for a given time interval) by any node. Network structure has been implemented as developed in [17].

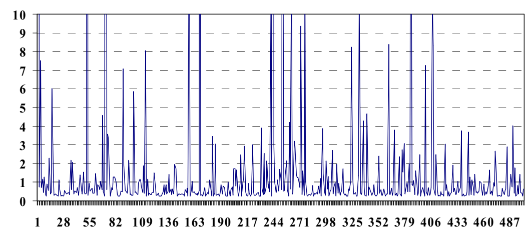

Figure 4: Incoming flow-traffic at a random node using the Pareto distribution for 500 secs ($1 < a < 2$).

Figure 5 illustrates the periodic sleep time in comparison with the non-periodic sleep time for unlimited buffer capacity. As seen the periodic sleep time is almost the half time of that of the device "live". In contrary the non-periodic time shows a significant reduction in active period and an increase in the mean sleep time. During simulation time it was shown that sleep time should not increase more than 71% at a time from previous measure because this will cause network partitioning and routing lock. According to figure 5 when MM streams are uniformly injected in the network sleep time decreases by almost 12%-15% compared with the sleep time occurring for the non-MM packets. This occurs because MM streams are injected in the network at discrete/random time slots, which influence the sleep time duration for each node. Figure 5 shows that if MM packets are traversing the network, sleep time can be further reduced by using sleep time estimation defined in (3).

Figure 6 shows the average MM packet delivery rate versus the average node notification interval. It is clearly shown that using the notations 2.1, 2.2 and 3, successfully transmitted MM packets can reach the delivery rate found for the periodic sleep-wake schedule. Non-periodic sleep time duration can also host MM packets since it allows significantly high rates in successful transmissions.

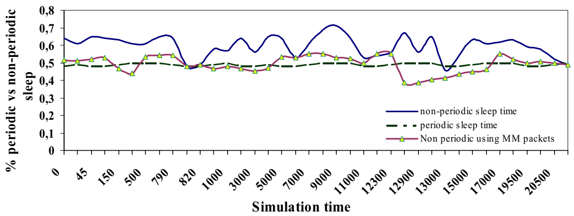

Figure 5: Comparison of periodic sleep time with non-periodic for unlimited node capacity.

Figure 7 shows the frequency use of caching technique, which is necessary for saving packets destined for a proper node. Having 0.3 as a mean value of the sleep time, the node which caches packets destined for a node laying in the sleep state, "saves" the MM packets by using the caching technique.

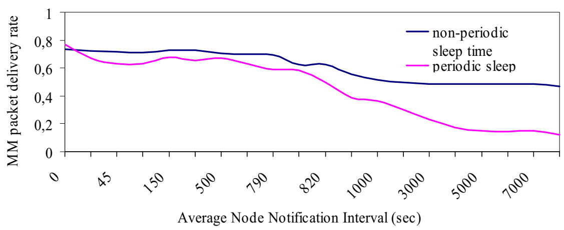

Figure 6: Illustration of the average MM packet delivery rate (reliability) versus the average node notification interval.

Figure 8 shows the mean number of hop count at any time in the network for successful transmissions. It is remarkable to point out that nodes in order to prevent network partitioning in the sleep state must not exceed the limit of 10. MM packets are particularly sensitive in large number of hop count. However a mean of 4.2 hops shows to be ideal for successful MM transmissions.

In figure 9 the mean number of nodes 'laying' in the sleep state is illustrated, for MM and don't care (mixed) traffic. It is easily extracted that the mean number of nodes reaches 5.9 nodes which are in the sleep state at any time in the network. From figure 9 it is indicated that unlimited capacity in each device could enable vulnerabilities for network connectivity. Roughly speaking when memory is unlimited, after some simulation steps, nodes will enter in a higher duration sleep time period. As a result network could split in parts (partitioning) causing significant reduction in performance, even if a limited number of nodes are allowed to enter in the sleep state. Hence a limited capacity for caching information destined for other nodes as shown in figure 9 might offer better connectivity and in turn network partitioning prevention. Figure 10 illustrates the network connectivity maintenance with respect to different capacity measures. It is extracted that unlimited memory for caching is not useful particularly for dynamically changing network. During simulation unlimited memory usually leads the network to unpredictable behavior and very often to partitioning. Thus placing a limit on caching capacity would enable higher network connectivity and better battery utilization by increasing the average sleep time duration. It is shown that for 64, 128, 256, 512 KB cached capacity ADCEC offers higher connectivity even in the presence of MM traffic.

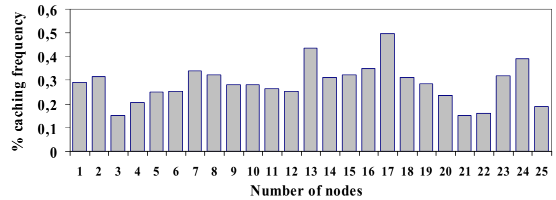

Figure 7: How frequently each node caches information for any other node (depending on network topology and node's mobility-in the presence of excessive traffic).

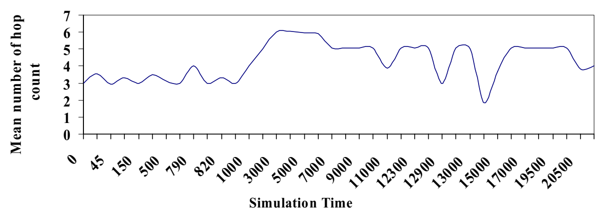

Figure 8: Mean number of hop count at any time in the network.

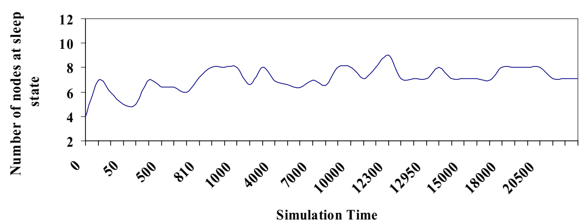

Figure 9: Mean number of nodes 'laying' in the sleep state (excessive traffic).

Figure11 shows the mean energy consumption in the network. It is very interesting to focus on the energy that is consumed utilizing the prioritized packets. The energy consumption is slightly higher than for don't care packets. A mean of 1542 μW corresponds to don't care packets while a mean 1789μW corresponds to MM packets. A difference of 13% trades-off the MM transmissions and future research will examine whether this difference enables further reduction if a different caching scheme will be used.

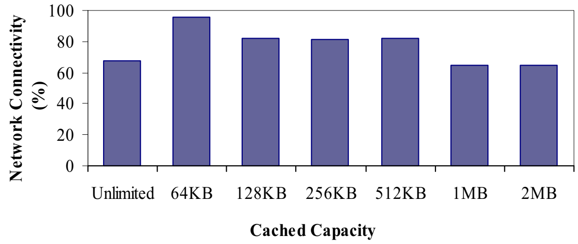

Figure 10: Network connectivity maintenance with respect to different capacity measures.

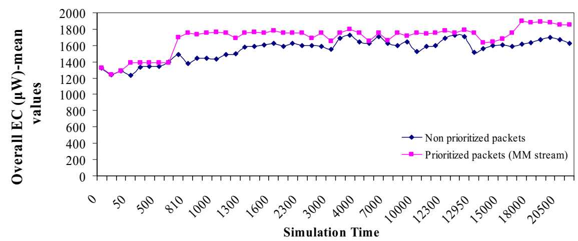

Figure 11: Mean Energy consumption in the network at any time during simulation.

5. Conclusions and further research

In this paper, we have implemented an Adaptive Dynamic Caching Energy Conservation (ADCEC) method for handling MM transmissions. This method bounds a partially asynchronous operation where each node evaluates dissimilar sleep-wake schedules based on each node's incoming sleep-history traffic. The main idea for conserving energy is the association of cached packets with the next sleep time duration of the intended node. Results have shown that unlimited memory for caching in wireless networks is disastrous compared with bounded caching capacities. Additionally it was shown that ADCEC method would enable a significant increase in the total average sleep time duration, the same time keeping network connectivity at high levels. This method ensures high reliability degree particularly for MM transmissions and remarkable energy conservation while successful transmissions occur.

If a wireless device needs to be connected with internet via other wireless networks or directly, a scope of interest could be the capabilities of such an enterprise to service mobile users on demand. The main challenge in wireless multi-hop ad-hoc networks is the efficient routing problem, which is aggravated by the node mobility. Therefore a routing technique that would enable an efficient routing scheme for web information retrieval by wireless devices for infrastructure-based mode or even by using the ad-hoc-based mode becomes a necessity with the tremendous growth of mobile users intending to access the web.

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