Power Efficient Wireless System for Ad-hoc Networks

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Abstract

In this paper, a power efficient wireless system ispresented for a large scale Ad-hoc network. In the proposedsystem, a whole Ad-hoc network is composed of one or morelocally time-synchronized subgroups. All communication linkswithin a subgroup are based on the local time synchronization.For reliable operation of the system, the operation of a nodeis presented.The power consumption of a node is evaluated bysimulation.

1. Introduction

Power consumption is one of the most important performancemeasures in designing a wireless system. Especially,in an Ad-hoc wireless network, power consumption becomesmore important, since most communication links are madebetween nodes operating with batteries. In most wirelesssystems, the power consumption of a node is dependent on them level of time synchronization between nodes. It is because thattime synchronization greatly influences the performance andpower consumption for a node to search neighboring nodes,detect disappeared nodes, and check the existence of a messagesent.

There have been many researches to design power efficientAd-hoc networks. In the case of an 802.11 Ad-hoc network,a scheduled rendezvous scheme has been used [1]-[3]. Withthe scheduled rendezvous, time synchronization is assumedbetween all nodes in the network. A randomly selected nodetransmits a beacon frame per each beacon interval for timesynchronization and network maintenance. With the scheme,it is assumed that all nodes are within communication distancesuch that any two nodes can make a direct link. Therefore, thisscheme is limited to small scale networks.

If nodes are distributed over a large area, it is difficult tomaintain global time synchronization between nodes, sinceit is not always possible to make a direct communicationlink between two arbitrary nodes in a network. To solvethis problem, fullyasynchronous wireless networks have beenstudied. A Cyclic-quorum based power management (CQPM)scheme is proposed to reduce the power consumption of nodesin a fully asynchronous network [5]-[9]. A CQPM scheme isbased on a set of codes and each node transmits beacon framesusing one of the predetermined codes. With CQPM, for a givenperiod of time which is determined by the product of the codelength and the beacon interval, a node transmits beacon framesseveral times and other nodes can detect at least one of thebeacons.

However, in many wireless environments, there are severalneighboring nodes around a node and it is relatively easyto maintain local time-synchronization between neighboringnodes within a short distance. Therefore, in this paper, wepresent a power efficient network system based on local time-synchronization.

In the proposed system, a whole networkis composed of several subgroups and all nodes within asubgroup are locally time-synchronized. If a node is locatedbetween the boundaries of two or more subgroups, it receivesbeacon frames from several neighboring subgroups. For reliableoperation of the system, a node periodically scans neighboringnodes. The receiver operation of a node is presented inthe proposed system.

2. Related Works

2.1. 802.11 Ad-hoc Power Management

Scheduled rendezvous power management is used in 802.11Ad-hoc [1]-[3]. With the Scheduled rendezvous, time synchronizationis assumed between nodes. A randomly selected nodetransmits a beacon frame per each beacon interval. Each nodeperiodically wakes up for T_{ATIM}, which is an ATIM (Ad-hocTraffic Indication Message) window, to receive beacon framesand check the existence of following message transmissionsfrom other nodes. If a node has data to transmit, it transmitsan ATIM frame to notify the data transmission. If a nodereceives an ATIM frame, it does not enter a sleep state toreceive data.

Scheduled rendezvous is effective in a small scale Ad-hocnetwork. However, if the scale of an Ad-hoc networkbecomes large with many nodes, it can cause several problemsin maintaining time synchronization and neighbor discovery,since it is not always possible to make a direct link betweentwo nodes [4].

2.2. Asynchronous Power Management

In a large scale wireless network, it is difficult to maintainglobal time synchronization between all nodes. Quorum-basedschemes have been proposed for a wireless network withouttime-synchronization [5]-[9]. Each node is assigned a codein a cyclic difference set. With the Quorum-based schemes,nodes can discover each other at least once in v consecutivebeacon intervals, where v is length of the code.

Among the Quorum-based schemes, Cyclic Quorum-basedPower Management (CQPM) uses cyclic difference sets, whichprovide the theoretically minimum active slot ratio [7].

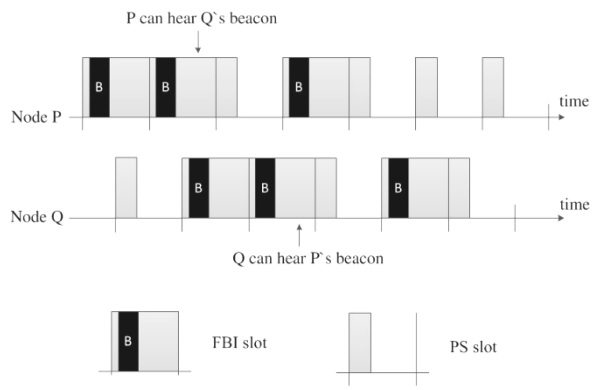

Figure 1. CQPM operation of two nodes

Fig. 1 shows the operation of two nodes using a cyclicdifference set. In Fig. 1, each node switches its operation withtime slot as a unit. The operation of nodes is divided into 2slots: Fully-awake Beacon Interval (FBI) slot, Power Saving(PS) slot [10]. There is at least one common FBI slot betweenthe same codes even if two nodes are full asynchronous in Fig.1.

It is possible to design various cyclic difference sets fordifferent lengths. A cyclic difference set is characterized by(v, k,), where v is the length of a code, k is the numberof FBI slots in the code, and is the number of minimumcommon slots between two codes. The cyclic difference setusing two nodes in Fig. 1 is a (7, 3, 1) set. With this cyclicdifference set, any two nodes can discover each other withinseven slots.

In a PS slot, a node wakes up for TATIM to receive an ATIMframe. If a node does not receive an ATIM frame, it enters asleep state until the next slot. If a node receives an ATIMframe, it remains in a receive state to receive data frames. Atthe start of a FBI slot, a node transmits a beacon frame. In therest of the slot, a node searches for beacon frames of othernodes.

3. Proposed System

In this section, a local-synchronization basedsystem is proposed for a large scale Ad-hoc network.

3.1. System Configuration

In the proposed Ad-hoc network, not all nodes are globally time-synchronized. However, it is assumed that neighboring nodes can synchronize timing and form a subgroup. The whole network is composed of several locally time-synchronized subgroups.

Compared with the global time-synchronization in a network, it is easier to achieve local time-synchronization. Each subgroup has its own time offset and all nodes in a subgroup are synchronized to the time offset. Because a node communicates with adjacent nodes most of the time, most communication links can be made with time synchronization.

If a node is located at the boundary between two adjacent subgroups, it becomes a member of the two subgroups and communicates with the two subgroups with different time offsets.

In each subgroup, a randomly selected node transmitsa beacon frame. The other nodes receive the beacon frame andsynchronize their timing using the beacon frame.

3.2. Receiver Operation

The proposed system is designed to reduce the powerconsumption of a node in a standby mode, when a node does not have data to transmit or receive. Therefore, we focus on the operation of a node without actual data transmission.

In the proposed system, while a node is in a receive state, it is in one of the following 3 substates: initial scan substate,full scansubstate, beacon reception substate.

3.2.1. Initial Scan Substate

When a node is powered on, it searches for neighboring nodes for initial scan time T_{INIT}.For this time interval, a node is in an initial scan substate.While in an initial scan substate, a node searches for beacon frames sent from neighboring nodes. By searching the beacon frames, it is possible to find the subgroups close to the node and obtain the timing offset information.

For reliable operation, it is necessary to set the T_{INIT}value much larger than a beacon interval. For example, if the beacon interval is 100 ms, the initial scan time can be set to 2 or 5seconds. In most practical scenarios, the initial scan time is generally negligible compare to the total time spent for theoperation of a node.

3.2.2. Full Scan Substate

After an initial scan, a node has the information of neighboring nodes and their time offsets. However, a node can move or the communication environments can be changed. Therefore, a node performs a periodic full scan for one beacon interval per every full scan interval $T_{FS}$to discover new neighboring nodes or detect disappeared nodes.

3.2.3. Beacon ReceptionSubstate

In the proposed system, a randomly selected node in a subgroup transmits a beacon frame per each beacon interval. The other nodes in the subgroup wake up to receive the beacon frame for beacon reception time T_{RXB} around the time instant when a beacon frame is sent. A node is in a beacon reception substate, when a node wakes up to receive a beacon frame for checking the existence of data transmission. After receiving a beacon frame,time offsets of nodes are adjusted using the received beacon frame.

If a network is composed of several subgroups as discussed in the system configuration, all nodes in a subgroup are time-synchronized to the time offset of the subgroup. If a node is located at the boundary of two or more subgroups, it can be a member of multiple subgroups. This node wakes up multiple times to receive beacon frames from the neighboring subgroups in a beacon interval.

4. Results

In this section, the power consumptions of CQPM and the proposed system are compared by simulation. System level simulators are built using NS-3 (Network Simulator 3), and power consumptions of nodes are measured.

With the proposed system, a randomly selected node in each subgroup transmits a beacon frame of 32 us length per beacon interval. Each node experiences log distance path loss channel. Beacon reception time and ATIM window are set to 5ms and5 ms, respectively. Power consumptions of a node are 244.2mW, 231mW and 10.6 mW, when it is in transmit, receive and sleep state, respectively [10].

Fig. 2 shows the measured power consumption of CQPMand the proposed system for different maximum neighbor discovery delay values. Maximum neighbor discovery delay is the time within which it can be guaranteed for a node to discover a new neighboring node with signal strength large enough for detection. With the proposed system, a node consumes less amount of power compared with CQPM. For example, if maximum neighbor discovery delay is 1second,the power consumption is decreased by 66.2 % compared withCQPM when a node belongs to one subgroup. Though a node belongs to two or three subgroups, the power consumption are still decreased by 55.8 % or 45.3 % compared with CQPM.

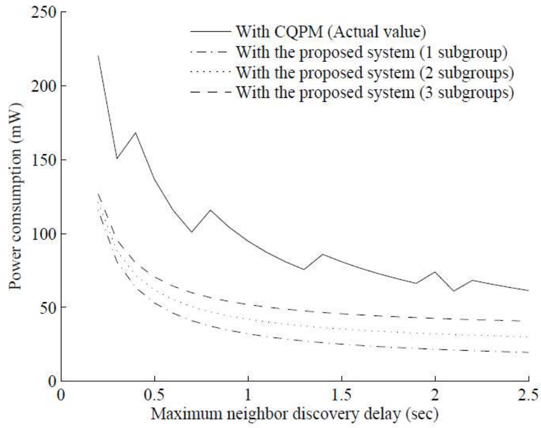

Figure 2. Power consumption of CQPM and proposed system with maximum neighbor discovery delay values

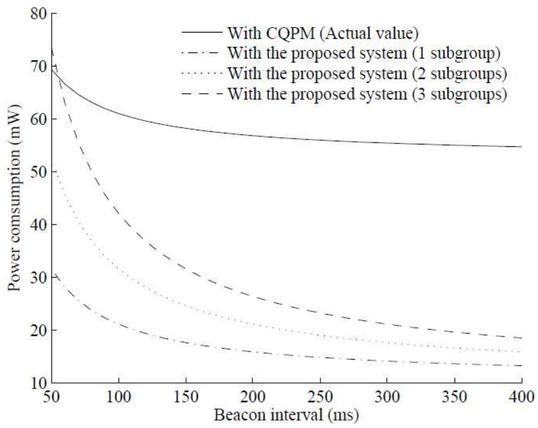

Figure3. Power consumption of CQPM and proposed system with different beacon interval

Fig.3 shows the measured power consumption of CQPMand the proposed system for several beacon interval values. When beacon interval is 100 ms, compared with CQPM, the proposed system reduces power consumption by 65.4 %, 48.2%, or 31.0 % when a node belongs to one, two, or three subgroups. When beacon interval is 300 ms, compared withCQPM, the proposed system reduces power consumption by75.5 %, 68.2 %, or 61.9 % when a node belongs to one,two, or three subgroups. Compared with CQPM, more powerconsumption can be reduced by using the proposed systemincreases, as the beacon interval increases.

5. Conclusion

In this paper, a power efficient wireless system is presentedfor a large scale Ad-hoc networks. If nodes are distributedover a large area, then it is difficult to maintain global time-synchronizationamong nodes. Therefore, in this paper, wepresent a wireless Ad-hoc system based on local time synchronization.

In the proposed system, a whole network is composedof several subgroups with local time synchronization within asubgroup.

If a node is located at the boundary of two or moresubgroups, then it receives beacon frames from multiplesubgroups. For the proposed system, the operation of a nodeis presented.

The power consumptions of CQPM and the proposed systemare compared by simulation. The simulation results showthat the proposed system can greatly reduce the power consumptionof a node compared with CQPM for most practicalwireless environments.

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