Energy-Efficient Strategy For Cooperative Multi-Channel MAC Protocols

[1]Dr. S. M. Afroz, [2]N. Geetha Rani, [3]V. Emanuel Raju
[1,2,3]Dept. of CSE, NIZAM Institute of Engg & Technology, Desh Mukhi, Hyderabad, AP, India

Abstract
Medium access control (MAC) protocols have been studied under different contexts for several years now. In all these MAC protocols, nodes make independent decisions on when to transmit a packet and when to back-off from transmission. In this paper, we introduce the notion of node cooperation into MAC protocols. Cooperation adds a new degree of freedom which has not been explored before. Our join Distributed Information SHaring (DISH) is a new join approach to designing Different channel MAC protocols. It aids nodes in their decision making processes by compensating for their missing information via information sharing through other neighboring nodes. This approach was recently shown to significantly boost the throughput of Different-channel MAC protocols. However, a critical issue for ad hoc communication devices, i.e., power efficiency, has yet to be addressed. In this paper, we address this issue by developing simple solutions which We compare five protocols with respect to the strategy and identify Unselfish DISH to be the right choice in general: (1) Conserves 40- 80% of power, (2) Maintains the throughput advantage gained from the DISH approach,(3) More than doubles the price efficiency compared to protocols without applying the strategy. On the other hand, our study shows that in-situ power conscious DISH is suitable only in certain limited scenarios. asynchronous Different-channel MAC protocol (CAM-MAC) is extremely simple to implement and, unlike other Different-channel MAC protocols, is naturally asynchronous.

Keywords
Control-Plane Cooperation, Unselfish DISH, In-Situ Power Conscious DISH, Wireless Networks

I. Introduction

Differently channelization's adds one more degree of freedom to wireless communications. The immediate benefit that can be reaped is an increase in spatial reuse by accommodating more simultaneous transmissions than is possible in single channel wireless networks Thus, aggregate network throughput can potentially is increased.

Using differently channels in communication is key to improving the quality of service for wireless networks, and as a result, Different-channel MAC protocol design has attracted substantial attention from the research community. Tremendous effort has been made and various design approaches have been proposed, most of which require either differently radios or time synchronization. Recently, [2] proposed a distinctive approach called DISH (Distributed Information Sharing), which uses a single radio but operates asynchronously. The authors designed a DISH-based protocol called CAM-MAC, in which neighboring nodes share control information with senders and receivers to compensate for their missed information in order to choose collision free channels or avoid busy receivers. Essentially, DISH can be viewed as a form of node cooperation, but there is a key difference: In traditional cooperation, intermediate nodes help relay data for source and destination nodes, which can be referred to as data-plane cooperation. On the other hand, DISH requires nodes to send/receive control information only and thus can be referred to as control-plane cooperation. This approach has been extensively evaluated in [2] via the CAM-MAC protocol. The results demonstrate significant throughput improvement compared to protocols not using DISH, including existing representative Different channel MAC protocols However, as DISH will be mainly used by ad hoc communication devices due to its distributed nature, power efficiency becomes a crucial issue since those devices are mostly battery powered. The prior work focused on throughput without considering power consumption. In this paper, firstly to understand this issue particularly from a quantitative perspective, we carry out simulation to compare CAM-MAC with two protocols, Non-DISH and Non-DISH-psm where:

- Non-DISH is CAM-MAC with the element of DISH removed, i.e., neighbors do not share information with senders and receivers who will hence make decisions on their own. Basically, this is a (traditional) non-join protocol.
- Non-DISH-psm is Non-DISH with an ideal power saving mode (psm), where each node only turns on its radio when sending/receiving packets addressed from/to it.

The simulation results show that, although the throughput of CAMMAC is 2.65 times Non-DISH and even more than Non-DISH-psm, its power consumption is 2.94 times Non-DISH-psm and comparable to Non-DISH (detailed results will be given in Section VI). This conveys that there is potentially large space for improvement in power efficiency for DISH.

To address this issue, we propose two power-efficient strategy, in-situ power conscious DISH and Unselfish DISH, in this paper. In the in-situ strategy, existing nodes rotate the responsibility of information sharing such that nodes without this responsibility can sleep when idle in order to save power. In the Unselfish strategy, additional nodes called altruists are deployed to take over the responsibility of information sharing so that all the existing nodes can sleep when idle. We conduct both qualitative and quantitative work to investigate the strategy with the following objectives:

- Reduce the power consumption,
- Maintain or not compromise the high throughput achieved via DISH, and
- Maximize price efficiency. Yet, the solution must be kept as simple as possible.

By comparing five protocols with respect to the strategy, our study recommends Unselfish DISH in general and in-situ Power conscious DISH only in certain limited scenarios.

We propose an asynchronous Different-channel MAC protocol using a single transceiver. The asynchronous mode of operation is made feasible through the introduction of cooperation. We make a key observation as illustrated in Fig. 1. Suppose a communication session is to be established between node A and B but these nodes have insufficient knowledge of the channel usage to select a safe (collision-free) channel. This channel usage information can be potentially acquired from idle neighbors (node C, D, E) if they maintain such information. Therefore, rather than selecting channels independently, nodes C, D and E help nodes A and B in making a good decision.

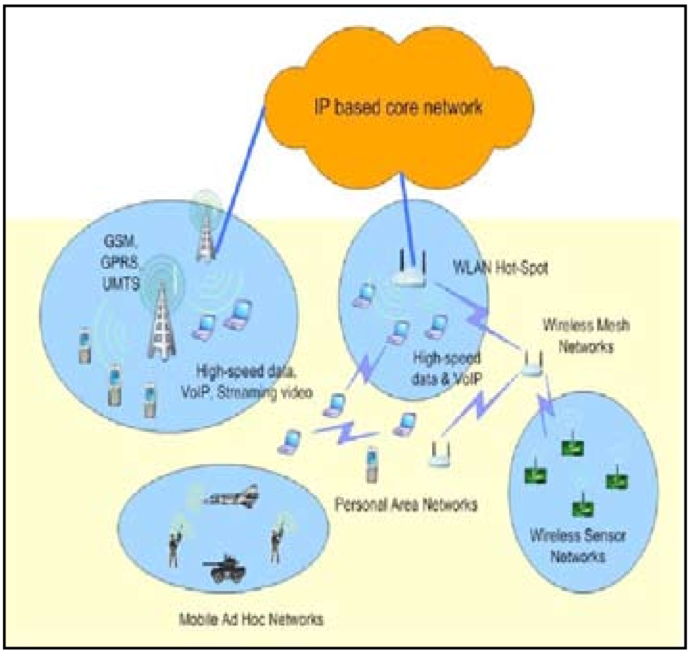

Fig. 1: The Observation that Leads to the Join Solution

Note that idle nodes naturally obtain channel usage information by overhearing transmissions in their vicinity. What is only needed is an appropriate and efficient cooperation mechanism to facilitate information sharing among nodes.

II. Linked Work

A. Power-Efficient Different-Channel MAC Protocols

There are a few proposals on this new topic. In ad hoc networks, PSM-MMAC lets nodes to choose to be awake or doze based on the estimated number of active links, queue length and channel condition. Addition to negotiating channels, it also negotiates time slots for nodes to sleep in.

- All cluster heads can directly communicate with each other and
- There are many sink nodes and hence no single sink bottleneck.

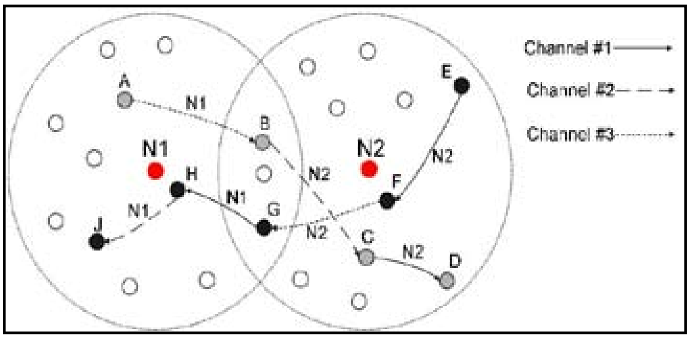

Fig. 2:

B. Power-Efficient Single-Channel MAC Protocols

In Ad-Hoc networks, Tseng et proposed three power-saving protocols for Different-hop scenarios, with time synchronization not required. These protocols differ in their power saving capability and neighbor discovery time, and can be chosen according to specific application needs.

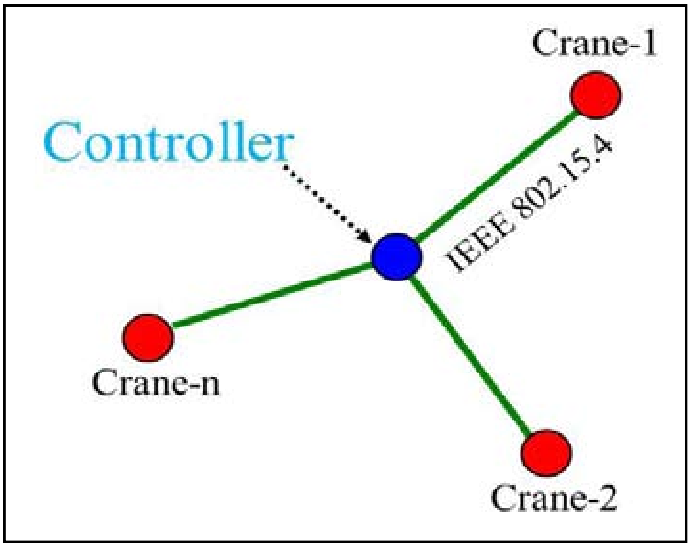

Fig. 3:

C. Different-Channel MAC Testbed

There are a few hardware implementations of Different-channel MAC protocols. Chereddiet reported a 4-node single-hop network testbed implemented on Linux with Adheres chipset, for a hybrid Different-channel MAC protocol proposed.

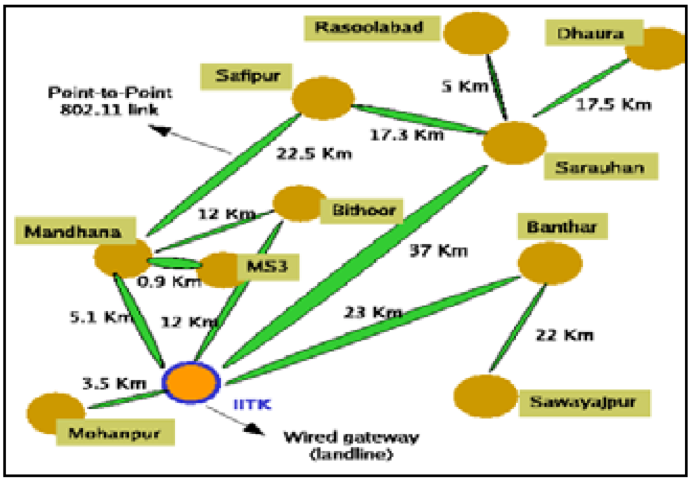

Fig. 4:

III. Accepting Dish

Control information is crucial to communications but can be missing due to various reasons such as shadowing and noise. The dominant reason, however, in a Different-channel environment, is that nodes fail to tune radios to certain channels in time, or that a radio can only listen to one channel at a time. This causes the Different channel coordination (MCC) problem which has two variants: (1) channel conflict problem, created when a node selects a busy channel (being used by other nodes), and (2) deaf terminal problem, created when a sender attempts to communicate with a receiver that is on different channel.

One category of solutions are to dedicate an extra radio to each channel or a common control channel in order not to miss information, The basic idea of DISH is to compensate for nodes' missing information via cooperation. It exploits neighboring nodes as a resource to "retrieve" missing information from, like from a distributed database, when needed. The need for Differently radios or time synchronization naturally becomes not necessary.

ISSN : 0976-8491 (Online) | ISSN : 2229-4333 (Print)

A. DISH-p: A DISH-based Protocol

For a more tangible ACCEPTING, we describe a DISH-based protocol called DISH-p (which was CAM-MAC described in [2]). In DISH-p, a sender and a receiver set up communication using PRA/PRB packets and then confirm using CFA/CFB packets. A neighbor will send INV packet if it identifies an MCC problem via the information conveyed by PRA/PRB. There is one control channel and differently data channels. On the control channel, a sender and a receiver exchange PRA/PRB to select a data channel, and then exchange CFA/CFB to confirm the channel selection. CCAP is introduced to mitigate the collision of differently simultaneously sent INVs. A neighbor who identifies an MCC problem will send INV only if it senses the control channel to be free for a period of Uniform [0, CCAP]. Hence a neighbor who sends INV will suppress its neighbors via CSMA.1 NCF is sent when the sender waits for CFB until timeout (due to the receiver receiving INV), in order to inform the sender's neighbors to disregard CFA.

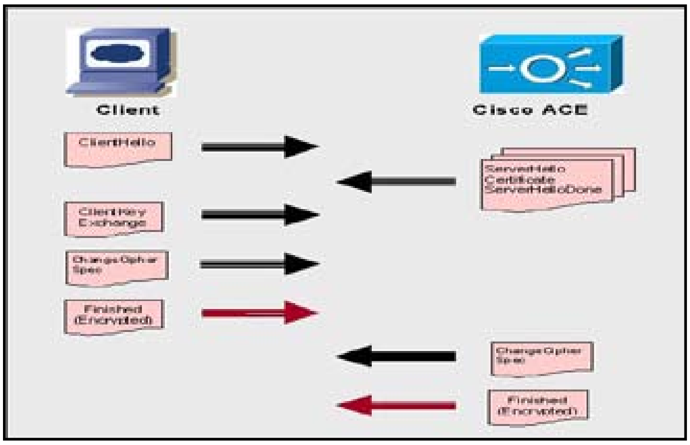

Fig. 5: Control Channel Handshake

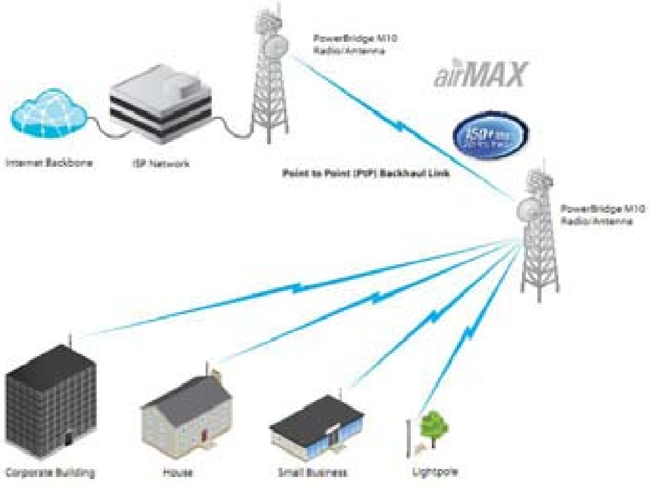

Fig. 6: Elements of the DISH-p Protocol

The applicable scenarios of the protocol are mesh networks and ad hoc networks, not sensor networks. In sensor networks, data packets are usually small and the overhead of the control channel handshake will be significant. Even using a packet train would not suit because sensing traffic is usually periodic and not burst.

IV. Power-Efficient Strategy

The main challenge to achieving power efficiency for DISH is that a prerequisite of information sharing is information gathering, a process that requires nodes to stay awake for overhearing, which presents a challenge for nodes to switch off radio when idle. The strategy we elaborate below meet this challenge and we also provide a qualitative analysis below.

A. In-Situ Power Conscious DISH

In this strategy, all the existing nodes rotate the responsibility of information sharing (i.e., cooperation) such that nodes without the responsibility can sleep when idle.2 there is two methods to implement this strategy:

- Probabilistic method
- Voting method

An apparent advantage of the in-situ strategy is that it does not require additional nodes. On the other hand, a runtime probabilistic or voting mechanism must be introduced and must be

- distributed,
- fair (in terms of power consumption), and
- Adaptive (to network dynamics such as traffic and power drainage). These would introduce considerable complexity and overhead. In addition, it has to consider other factors as listed below.

Third, how to integrate a probabilistic or voting mechanism into a legacy DISH protocol is a non-trivial problem and a viable solution is yet to be found.

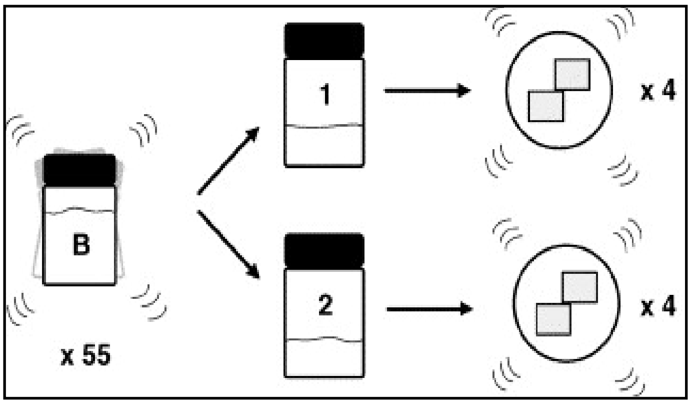

Fig. 7:

B. Unselfish DISH

In this strategy, additional nodes called altruists are de-played to take over the responsibility of information sharing (i.e., cooperation) from the existing nodes, which we call peers to distinguish from altruists, so that peers can sleep when idle. Altruists are the same as peers in terms of hardware, but are different in terms of software: they solely cooperate (do not carry data traffic) and always stay awake. Peers only carry data traffic and need not to cooperate; they are like nodes in traditional (non-DISH) networks and thus can adopt a legacy sleep-wake scheduling algorithm, where a lot of choices are available

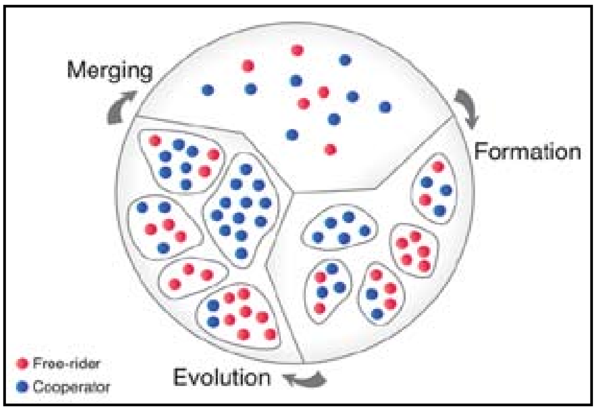

Fig. 8:

C. Protocols to Investigate

In the sequel, we investigate Genie In-Situ and Unselfish, which are two protocols made by applying the above two strategy to DISH-p (original DISH protocol) respectively. For the purpose of comparison, we also need to introduce two non-DISH protocols, one with and the other without power saving, viz., Non- DISH and Non-DISH-psm. The following describes all the five protocols.

1. DISH-p
2. Non-DISH.
3. Non-DISH-psm
4. Genie In-Situ
5. Unselfish

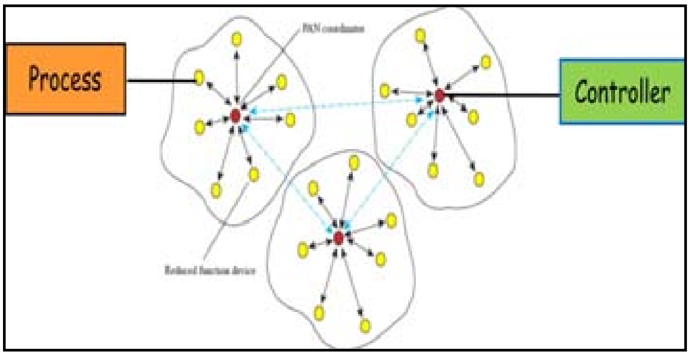

Fig. 9:

D. Issues to Investigate There are three relevant issues:

1. Node deployment
2. Price efficiency.
3. Throughput-power trade-off

In the rest of the study we assume an ad hoc network with static topology. Each node has a single half-duplex radio that can dynamically switch among all available channels but can only use one at a time. One channel is designated as a control channel and the others as data channels. Data channel selection is random, meaning that a sender/receiver randomly selects one from a list of data channels that it deems free based on its knowledge which it dynamically updates (e.g., channel usage table as in Fig. 1c).4 Finally, we assume all links are bidirectional, i.e., if node u can hear node v then v can hear u as well.

V. Price Efficiency

We propose a metric Called Bit-Meter-Price (BMP) ratio to measure the price efficiency of a protocol.

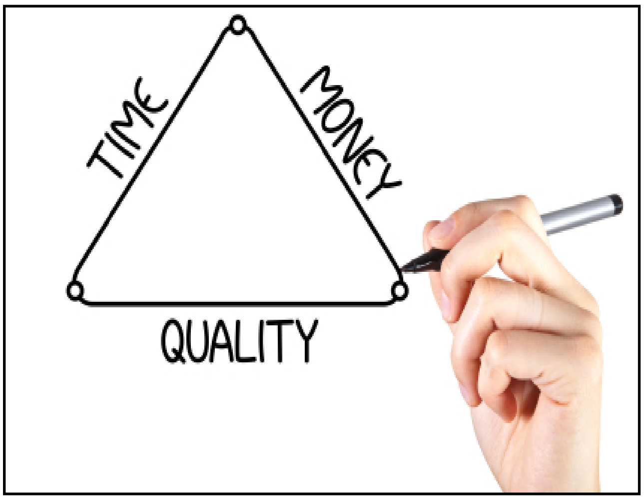

Fig. 10:

A. Bit-Meter-Price Ratio

BMP is a performance metric defined for a Network:

$$BMP = (Np + Na) \bullet max(Pp)max\ Pmax)$$
$$pa)-1$$

Here is a vector of all the flows throughput, a vector of all the flows source-to-destination Euclidean distances, Np and Na are the total number of peers and altruists, respectively, Pmax and Pmax are the maximum power consumption rate among all the peers and the altruists, respectively, b0 = e0/c0, and e0 and c0 are the initial power and the unit price of a node (altruists and peers are the same devices), respectively. BMP can be understood as Throughput (F) Distance (D) words, BMP is the total amount of successfully delivered data Different plied by end-to-end distance during the network's operational time and normalized by system resources. So the higher BMP, the better performance. The unit of BMP is bit-m/$. In (6), lifetime is defined as the time until any node (a peer or an altruist) runs out of power. As peers are the nodes who actually perform the essential task of a network (transferring data), it also makes sense to define lifetime in terms of peers only, viz., L = e0/Pmax. It is easy to see this alternative definition is to the favor of Unselfish because it only leads to a higher BMP for Unselfish. But we still use definition (6) in our study.

B. BMP Evaluation

We conduct simulation and compute BMP for the five protocols. Since all the protocols use the same devices, the value of b0 does not affect comparison and we set b0 = 1J/$. For Unselfish, we deploy altruists with density palt = 1.31/r2 in Different-hop networks according to Section IV-B, and deploy a single altruist in single-hop networks which achieves full cooperation coverage. Each source node generates data at 25kbps in Different-hop networks and 160kbps in single-hop Networks.

- Throughput
- Distance
- Lifetime.
- Price

1. The BMP of Non-DISH gradually declines due to the lack of information sharing,
2. The BMP of Non-DISH-psm drops remarkably due to the lack of both information sharing and gathering,
3. The BMP of DISH-p largely maintains, and
4. The BMP of Unselfish and that of Genie In-Situ both rise as by virtue of power conservation of the strategy as well as the throughput benefit of DISH.

VI. Throughput-Power Tradeoff

This section zooms in to specifically inspect the throughput and power performance.

A. Different-Hop Networks

The simulation setup remains the same, and the results are shown in Fig. 6 for palt = 1.31/r2 and peer = 10/r2 (the results for peer = 20/r2 are similar and omitted).(throughput) clearly indicates three levels as low, medium, and high, corresponding to Non-DISH-psm, Non-DISH, and the three DISH protocols (DISH-p, Genie In- Situ and Unselfish For power consumption both Unselfish and Genie In-Situ save a remarkable amount (40-80%) of power consumed by DISH-p or Non-DISH. Note worthily, Unselfish even outperforms Non-DISH-psm (though slightly) under higher traffic load because Non DISH-psm seems to be the most power frugal protocol

B. Single-Hop Networks

Unselfish uses one altruist in single-hop networks. The simulation was conducted under high traffic load (source nodes are always backlogged) and low traffic load (traffic generation rate is 160kbps) respectively, and the results are Summarized Unselfish DISH conserves a significant amount of power and well maintains the throughput benefit of DISH.

VII. Hardware Implementation

We have also implemented four protocols on COTS hard-ware (all the five except Genie In-Situ which requires a no implementable genie). To the best of our knowledge, these are the first full implementation of asynchronous Different channel
MAC protocols for ad hoc networks

A. Implementation

1. Platform Selection
2. Overcoming Limitations
3. Virtual Collision Detection
4. They are empirical and lack in accuracy, and according to [46¬48], it is still controversial whether RSSI or LQI is a better indicator for link quality.
5. Our technique virtual collision detection sequences.

B. Experiments

For visualization purposes, we use the three LEDs on each Telos B mote to indicate specific events of interest (a maximum number of 23 = 8 events can be represented). For example, a blue LED indicates an ongoing control channel handshake, a green LED indicates an ongoing data channel handshake, and a red LED indicates transmitting a join message. Other events are indicated by LED combinations.

VIII. Discussion

A. Limitations

Unselfish DISH becomes less effective when there are only a few peers (compared to the number of channels) or traffic is light, in which case channel contention is very mild.

B. Alternative Methods for Unselfish

DISH an alternative method for Unselfish DISH is to add one more radio on a few peers and let these additional radios act as altruists.

C. Power Fairness

A possible concern is that, being always a wake, altruists may be

IX. Conclusion

Distributed information sharing (DISH) can significantly boost the system throughput for Different-channel MAC protocols, but it also heighten the power consumption due to its information sharing component (which subsumes information gathering as well). In this paper, we propose two power-efficient strategy and conduct a comparative study on five protocols that differ in the usage of DISH and the strategy. Both simulations and test bed experiments show that Unselfish DISH (1) is a very simple strategy which does not involve protocol re-design or incur additional runtime overhead, (2) substantially reduces power consumption while maintaining (sometimes even enhancing) the throughput benefit from DISH, and also (3) apparently improves price efficiency. The other strategy, in-situ power conscious DISH, is suitable for applications with few nodes or light traffic, or those that preclude using additional

References

[1] A. Nasipuri, J. Mondhe,"Differentchannel CSMA with signal powerbased channel selection for Differentchip wireless networks", in IEEE VTC, 2000.
[2] Join asynchronous Differentchannel MAC: Design, analysis, and implementation, IEEE Transactions on Mobile Computing, Vol. 8, No. 3, pp. 338–52, March 2009.
[3] S.-L. Wu, C.-Y.Lin, Y.-C.Tseng, J.-P. Sheu,"A new Different-channel MAC protocol with on-demand channel assignment for Different-hop mobile Ad-Hoc networks", in I-SPAN, 2000.
[4] A. Nasipuri, J. Zhuang, S. R. Das,"A Differentchannel CSMA MAC protocol for Differentchip wireless networks", in WCNC,1999.
[5] A. Nasipuri, J. Mond he,"Differentchannel CSMA with signal Power based channel selection for Different hop wireless networks", in IEEE VTC, 2000.
[6] N. Jain, S. R. Das, A. Nasipuri,"A Differentchannel CSMA MAC protocol with receiver-based channel selection for Differentchip wireless networks", in IEEE ICCCN, 2001.
[7] A. Adya, P. Bahl, J. Padhye, A. Wolman,"A Different-radio unification protocol for IEEE 802.11 wireless networks", in IEEE Broadnets, 2004.
[8] R. Maheshwari, H. Gupta, S. R. Das,"Differentchannel MAC protocols for wireless networks", in IEEE SECON, 2006.
[9] J. Chen, S. Sheu, C. Yang,"A new Differentchannel access protocol for IEEE 802.11 ad hoc wireless LANs", in PIMRC, 2003.
[10] J. So, N. Vaidya,"Different-channel MAC for ad-Hoc networks: Handling Different-channel hidden terminals using a single transceiver", ACM MobiHoc, 2004.
[11] J. Zhang, G. Zhou, C. Huang, S. H. Son, J. A. Stankovic, "TMMAC: an power efficient Different-channel MAC protocol for Ad-Hoc networks", in IEEE ICC, 2007.
[12] A. Tzamaloukas, J. Garcia-Luna-Aceves,"Channel-hopping Differentple access", in IEEE ICC, 2000.
[13] "Channel-hopping Differentple access with packet trains for ad hoc networks", in IEEE Device Differentmedia Communications, 2000.
[14] P. Bahl, R. Chandra, J. Dunagan,"SSCH: Slotted seeded channel hopping for capacity improvement in IEEE 802.11 ad-hoc wireless networks", in ACM MobiCom, 2004.
[15] H.-S. W. So, G. Nguyen, J. Walrand,"Practical synchronization techniques for Different-channel MAC", in ACM MobiCom, 2006.
[16] L. Huang, T.-H. Lai,"On the scalability of IEEE 802.11 Ad-Hoc networks", in ACM MobiHoc, 2002, pp. 173–182.
[17] S.-Y. Ni, Y.-C. Tseng, Y.-S. Chen, J.-P. Sheu,"The broadcast storm problem in a mobile ad hoc network", in ACM MobiCom, 1999.
[18] M. B. Yassein, M. O. Khaoua, L. M. Mackenzie, S. Papanastasiou,"Improving the performance of probabilistic flooding in manets", in International Workshop on Wireless Ad-hoc Networks (IWWAN), 2005.
[19] Q. Zhang, D. P. Agrawal,"Dynamic probabilistic broadcasting in manets", J. Parallel Distrib. Comput., Vol. 65, pp. 220–233, 2005.

[20] C. L. Barrett, S. J. Eidenbenz, L. Kroc, M. Marathe, J. P. Smith,"Parametric probabilistic sensor network routing", in ACM WSNA, 2003.
[21] T. Roosta, M. Menzo, S. Sastry,"Probabilistic geographic routing in ad hoc and sensor networks", in International Workshop on Wireless Ad-hoc Networks (IWWAN), May 2005, pp. 122–131.
[22] W. R. Heinzelman, A. Chandrakasan, H. Balakrishnan, "Powerefficient communication protocol for wireless microsensor networks", in IEEE HICSS, 2000.
[23] O. Younis, S. Fahmy,"Distributed clustering in ad-hoc sensor networks: A hybrid, power-efficient approach", in IEEE Infocom, Hong Kong, China, March 2004.
[24] Y. Xu, J. Heidemann, D. Estrin,"Geography-informed power conservation for ad hoc routing", in ACM MobiCom, Sept. 2001.
[25] B. Chen, K. Jamieson, H. Balakrishnan, R. Morris,"Span: An power-ecient coordination algorithm for topology maintenance in ad hoc wireless networks", in ACM MobiCom, Sept. 2001.
[26] L. Buttyn, P. Schaffer,"PANEL: Position-based aggregator node election in wireless sensor networks", in IEEE MASS, Oct. 2007.
[27] M. Qin, R. Zimmermann,"VCA: An power-efficient voting-based clustering algorithm for sensor networks," Journal of Universal Computer Science, Vol. 12, No. 1, pp. 87–109, 2007.
[28] J. Bruck, J. Gao, A. Jiang,"Localization and routing in sensor networks by local angle information", in ACM MobiHoc, May 2005.
[29] A. Caruso, S. Chessa, S. De, A. Urpi,"GPS free coordinate assignment and routing in wireless sensor networks", in IEEE Infocom, March 2005.
[30] . Luo, M. Motani, V. Srinivasan,"CAM-MAC: A join asynchronous Different-channel MAC protocol for ad hoc networks", in IEEE Broadnets, San Jose, CA, USA, October 2006.
[31] Cisco Systems Inc.,"Cisco aironet 350 series client adapters", [Online] Available: http://www.cisco.com/en/US/products/hw/wireless/ps4555.
[32] L. M. Feeney, M. Nilsson,"Investigating the power consumption of a wireless network interface in an ad hoc networking environment", in IEEE Infocom, 2001.

Dr. S. M. Afroz is a diligent, research oriented gentleman with a vast experience of seventeen years in the field of teaching. He also handled various other responsibilities related to administration and discipline besides academics. Through out his career, Dr. S. M. Afroz has been showing keen interest in academic and research development N.Geetha Rani is diligent, Assistant Proffeser with a vast experience of five years in the field of teaching. She taught very well, conduct seminars and give suggestions to students very well. Through out her career, N.Geetha Rani has been showing keen interest in academic and research development.

N.Geetha Rani is diligent, Assistant Proffeser with a vast experience of five years in the field of teaching. She taught very well, conduct seminars and give suggestions to students very well. Through out her career, N.Geetha Rani has been showing keen interest in academic and research development.

Vinukonda.Emanuel Raju received his B.Tech degree in CSE from Dr.Samuel George Institute of Engg & Technology, Markapur, Prakasam(D.t) in 2009. The M.TECH degree in CSE from NIZAM Institute of Engg & Technology, Deshmukhi, Near Ramoji film city, Hyderabad, India, in 2012.At present, He is engaged with "Energy Efficient Strategies for Cooperative Multi-Channel MAC Protocols ".