Cooperative Load Balancing and Dynamic Channel Allocation for Cluster-based Mobile Ad Hoc Networks

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Abstract-- Wireless communication has been around for over a century and has within the last decade become a regular mode of communication in people's everyday lives, thanks to the success of cellular and WiFi communication. Recently, researchers have focused on eliminating the need for fixed infrastructures in wireless communication, which has led to the development of ad hoc networks. A mobile ad hoc network (MANET) further considers node mobility within the ad hoc setting. Efficient use of resources and adaptation are vital in order to create a high performance MANET. This dissertation addresses the efficient use of network resources to obtain the desired quality of service and performance in MANETs.

Keywords: *Mobile adhoc networks, bandwidth efficiency, distributed dynamic channel allocation*

I. INTRODUCTION

A mobile ad hoc network (MANET) is a self-configuring communication system that uses the nodes themselves as not only sources and sinks but also routers. Nodes in a MANET are typically battery operated devices with limited-range, half-duplex radios for communication. MANETs are easy to set up and use since their operation does not depend on any fixed infrastructure. There are many applications that can benefit from MANETs such as:

- Military tactical operations. A communication network that relies on a
- Certain infrastructure is not desirable for military tactical operations, as it constitutes a soft spot in hostile environments. Elimination of the need for the hard/impossible to set up fixed infrastructure makes MANETs perfect candidates for such operations.
- Search and rescue missions. Oftentimes search and rescue missions are performed in remote locations with no communication infrastructure, such as the top of a mountain, the middle of a forest or inside a cave. MANETs are easy to use communication systems for such scenarios.
- Disaster relief. MANETs provide communication in environments where existing infrastructure is destroyed or left inoperable.
- Law enforcement. Law enforcement operations can be extended to include locations with no communication infrastructure. MANET systems provide fast and secure communication in such scenarios.
- Commercial use. MANETs can be used to support data exchange between people and applications in large meetings and conventions.

MANETs are unique among communication networks, as can be observed from the vital application areas. However, the unique characteristics required by these applications necessitate unique solutions and differentiate MANETs from other conventional networks. There are various challenges that have to be taken into account when designing a MANET. First of all, the communication channel between the nodes in the network is highly unreliable. A MANET operates over wireless channels that incur higher bit errors compared to wired interfaces. MANET protocols have to be designed with the assumption of an erroneous channel. MANETs also are designed to work in any environment, whether it is a desert, forest or mountainous region. The lack ofa-priori knowledge about the propagation characteristics of the wireless medium also presents challenges to protocol design for MANETs.

Node mobility is another challenge in the design of MANETs. The topology of a MANET can change not only with changing propagation characteristics of the medium but also due to the mobility of the nodes in the network. In order to reliably convey information, MANET protocols have to include mechanisms for proper mobility management. Having limited storage and computational capabilities further restrict the range of algorithms that can be used in MANETs.

Moreover, MANETs have limited bandwidth and energy resources. The assumption of mobility inherently limits the energy supply available at each node. Thus, it is important for a MANET to be energy efficient and energy aware. Typically, the bandwidth available for the communication is also limited. The erroneous channel characteristics further decrease the channel capacity, making bandwidth a valuable resource for MANETs. Efficiency in using the bandwidth and energy resources and a carefully adjusted spatial reuse algorithm are some of the key criteria for the design of MANET algorithms. Security (due to potentially hostile environments), quality of service requirements (due to demanding applications), and scalability can be counted among the other challenges in the design of a MANET.

A. Motivation and Goals

The previous section defined MANETs, their potential application areas, and the challenges in their design. In order to meet the demanding quality of service (QoS) and performance requirements, it is crucial for MANET protocols to adjust the utilization of bandwidth (a common resource) and energy (a node specific resource) according to the dynamic operating conditions. The overall efficiency of the system depends strongly on the careful adjustment of the resource usage in 4 all layers of the protocol stack, from the physical layer on up to the application layer.

The MAC protocol is the key element in the protocol stack that determines the ability of a wireless network to meet application requirements, since the MAC protocol has a direct impact on throughput, Quality of Service (QoS), energy dissipation, fairness, stability, and robustness.

In particular, coordinated channel access schemes provide support for QoS, reduce energy dissipation, and increase throughput for low-to-mid noise levels and for dense networks. MH-TRACE and IEEE 802.15.3 are examples of such coordinated protocols. The IEEE 802.15.3 protocol is specifically designed for high-rate and short range wireless personal area networks (WPANs). MHTRACE is designed for mid-range medium-rate transmissions. Both of those algorithms use a TDMA structure together with soft clustering of the nodes for channel access, as this approach has been shown to provide satisfactory performance in terms of QoS and energy dissipation.Many of the protocol parameters in cluster-based protocols are set a-priori based on estimates of network conditions and based on a specific physical layer. TDMA parameters, which determine the amount of spatial reuse and interference, distribute the available bandwidth among clusters so as to reduce the interference throughout the network. Reducing the interference is a desirable goal since high interference leads to high error rates, decreasing the throughput as studied. However, reducing the available bandwidth per cluster also decreases the capacity per cluster. Non-uniform node distribution and node mobility may increase the local load above the cluster capacity, resulting in dropped packets and decreasing the throughput for real-time traffic. The decision of how to set these parameters should thus be based on this trade-off and would be affected by various conditions such as node density and physical layer parameters. An analysis that describes the relationship between the protocol parameters and the performance metrics isneeded to ensure efficient use of the limited resources in MANETs, and we develop such a model in this dissertation.

The conditions in which a MANET operates may change over time. No uniform traffic loads are typical in MANETs due to intrinsic characteristics such as dynamically changing environment conditions and node mobility. The network designs should include dynamic channel allocation strategies in order to support non-uniform traffic. The objective of these strategies is to distribute the channel resources to the nodes that require channel access while taking the interference levels and spatial reuse into consideration. Although various dynamic channel allocation strategies have been proposed for other network types such as cellular networks, due to the specific characteristics of MANETs, these strategies are not directly applicable. In this thesis, we propose a dynamic channel allocation strategy that sets operating conditions on the fly for efficient resource utilization for MANETs. We further propose a cooperative load balancing algorithm for smoothing out the non-uniformity in the load distribution and combine it with the dynamic channel allocation strategy.

Data dissemination is another topic that is very important for reducing redundant usage of resources. The data generated in a MANET is oftentimes intended to be sent to more than one destination. One-to-many group communications are generally classified into two types: network-wide broadcasting and multicasting. In network-wide broadcasting the objective is to distribute the generated data to all the nodes in the network. However, the objective of multicasting is to deliver the data to a subset of the nodes in the network. In general, the overhead added to the packets in multicasting protocols is more than the overhead in networkwide broadcasting protocols. On the other hand, multicasting protocols prevent redundant transmissions on the parts of the network in which no multicast member resides. Investigating the trade-offs between multicasting and broadcasting in order to determine the conditions that make one of them preferable over the 6 other is needed to increase the efficiency and is discussed in this dissertation.

MANETs may operate in close proximity to other networks such as wireless sensor networks, cellular networks, or other MANETs. Optimizing networks internally, aiming to achieve individual objectives considering only individual network resources and using only local information about the network and ignoring co-located networks' resources and the effects the networks have on each other, results in sub-optimal overall performance. Symbiotic Networking, on the other hand, enables the mutual support of co-located networks through the symbiotic integration of otherwise independent networks. In symbiotic networking, networks not only can cooperate rather than compete in using common resources such as bandwidth but also help each other in routing the data following each network's individual goals. We examine how to exploit this cooperation in symbiotic networks in this dissertation.

Although simulations are efficient tools to comparatively evaluate the efficiency of the protocols, they cannot reflect many of the challenges for real implementation of these protocols, such as clock-drift, synchronization, imperfect physical layers, and interference from devices out of the system. Such issues may cripple a protocol that otherwise performs very well in software simulations. Thus, hardware implementation is essential for testing a protocol before any practical deployment. We focus on the implementation challenges of cooperation for a communication system and implement CDCA-TRACE protocol on a software defined radio platform. It is clear that the efficient usage of the resources in MANETs is an important topic that is affected by various factors. This dissertation describes our analysis, design and simulations for MAC and Routing layer protocols that ensure efficient resource utilization in MANETs. My thesis is that a protocol architecture for MANETs that dynamically adapts to changing conditions based on cooperation and information sharing leads to more efficient use of the system resources compared to competition based architectures.

II. RELATED WORK

A. *Medium Access Control in MANETs*

In wireless communications, the goal of the medium access control (MAC) protocol is to efficiently utilize the wireless medium, which is a limited resource. The effective use of the channel strongly determines the ability of the network to meet application requirements such as quality of service (QoS), energy dissipation, fairness, stability, and robustness, Based on the collaboration level, MAC protocols can be classified into two categories: coordinated and non-coordinated. Channel access in non-coordinated protocols is typically based on a contention mechanism between the nodes. IEEE 802.11 is an example of a non-coordinated protocol. Although it is easier to support non-uniform trafficwith non-coordinated protocols, these protocols are unsuitable for highly loaded networks due to the contention mechanism. On the other hand, in coordinated channel access protocols, the medium access is regulated, making them better suited for networks where the network load is high. IEEE 802.15.3, IEEE 802.15.4, and MH-TRACE are examples of such coordinated protocols. Coordinated channel access schemes provide support for QoS, reduce energy dissipation, and increase throughput for low-to-mid noiselevels and for dense networks. However, these protocols perform poorly under non-uniform traffic loads.

IEEE 802.15.3, IEEE 802.15.4 and MH-TRACE all manage the multiple access scheme through a TDMA structure, as this approach has been shown to provide satisfactory performance in terms of QoS and energy dissipation. MH-TRACE further uses a soft clustering approach where the clustering mechanism is utilized only for providing channel access to the member nodes. Hence, each node is capable of communicating directly with every other node provided that they are within communication range of each other. IEEE 802.15.3 and IEEE 802.15.4 only allow communication among the members of distinct clusters (piconets) in their peer to peer mode, while in star topology mode, nodes in distinct clusters can only communicate through their piconet controllers.

1) *Clustering Approaches Regardless of the partitioning scheme*

The main consideration in forming clusters is the load distribution in the network. Clusters should be formed in such a way that they are able to meet the demand for channel access of the nodes in the cluster as much as possible. When the cluster is not able to meet the demand, either some of the transmissions are deferred (better suited for guaranteed delivery traffic) or the packets are dropped (better suited for best effort traffic). Thus, while designing a protocol or determining the performance of a specific protocol, the load distribution has crucial importance. Clustering approaches may be classified as soft and hard clustering. In hard clustering approaches, such as GSM networks, nodes belong to the cluster in which they operate.

Direct communication is only possible within the cluster. On the other hand, in soft clustering approaches such as MH-TRACE, nodes interact with cluster heads only to obtain channel access. There is no membership relation between the nodes and the clusters. In other words, nodes are able to communicate directly with the nodes of other clusters and to choose the cluster from which they receive channel access. In general, soft clustering approaches are superior to hard clustering approaches in distributing the load evenly among clusters. On the other hand, soft clustering approaches tend to be more vulnerable to interference and collisions among co-frame clusters, since the boundaries of the clusters are not strict. In this dissertation, we consider soft clustering approaches.

2) *MH-TRACE Summary*

In this work, we analyze the performance of soft clustering protocols to determine how to best set their parameters for efficient use of the channel resources. Specifically, we analyze the MH-TRACE protocol. Here we briefly explain the clustering mechanisms of MH-TRACE. A detailed description of MH-TRACE is available in MH-TRACE, time is divided into super frames of equal length, as shown in Fig. 1, where the super frame is repeated in time and further divided into frames.

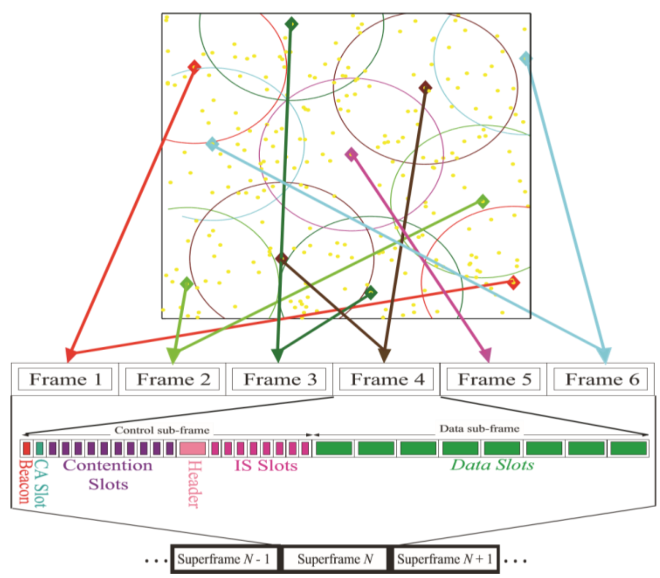

Fig 1: A snapshot of MH-TRACE clustering and medium access.

3) Mathematical Modeling of MAC Performance

The most direct approach to determine the MAC performance is to obtain samples of field measurements on the performance metrics. However, the difficulty in implementation on real hardware and taking a large set of field measurements make this method impractical for most cases, and not the best approach in the protocol design stage. It is easier and more convenient to implement a protocol on a simulation platform. Thus, simulation studies are the most widely used methods to evaluate the performance of protocols. However, it is impractical to determine the performance of a protocol for large sets of conditions as simulations require excessive amounts of processing power and time. Analytical models are the most suitable tools to obtain insight into the performance of a MAC protocol.

4) Dynamic Channel Allocation Strategies

The responsibility of the MAC layer is to coordinate the nodes' access to the shared radio channel, minimizing conflicts. In a multi-hop network, obtaining a high bandwidth efficiency is only possible through exploiting channel reuse opportunities. Indeed, efficient utilization of the common radio channel has been the center of attention since the early development stages of wireless communication.

Cidon et al. present a distributed dynamic channel allocation algorithm with no optimality guarantees for a network with a fixed a-priori control channel assignment. Alternatively, there are various game-theoretic approaches to the channel allocation problem in ad hoc wireless networks. Gao et al. model the channel allocation problem in multi-hop ad hoc wireless networks as a static cooperative game, in which some players collaborate to achieve a high data rate. However, these approaches are not scalable, as the complexity of the optimal dynamic channel allocation problem has been shown to be NP-hard.

In a multi-hop wireless network, CSMA techniques enable the same radio resources to be used in distinct locations in a network, leading to increased bandwidth efficiencies at the cost of possible collisions due to the hidden terminal problem. Different channel reservation techniques are used to tackle the hidden terminal problem. Karn et al. use an RTS/CTS packet exchange mechanism before the transmission of the data packet. 802.11 distributed coordination function (DCF) uses a similar mechanism but adds an ACK packet indicating the successful reception of the packet. Although this handshake reduces the hidden node problem, it is inefficient under heavy network loads due to the exposed terminal problem. Several modifications to the RTS/CTS mechanisms have been proposed to increase the bandwidth efficiency including use of multiple channels such as.

However, these approaches attempt to solve the problem of channel assignment when there is a single intended destination of each transmission and do not cover group communication. We are interested in MANET scenarios where the destination of the generated packet is not a specific node in the local neighborhood but all the nodes in the immediate neighborhood of the transmitter. Such a scenario is only covered with 802.11 DCF basic access mode where the RTS/CTS mechanism is disabled.

In coordinated MAC protocols, channel assignment is performed by channel coordinators. Channel reuse is incorporated into the system through use of the same channel by coordinators that are spatially separated. The cellular concept that regulates channel access through fixed infrastructure called base stations also forms the basis of the widely deployed GSM systems.

B. Routing in MANETs

1) Group Communications

Group communications is essential for many applications in mobile ad hoc networks, including supporting electronic classrooms, tactical military communication, and communication in disaster recovery missions. One-to-many group communications are generally classified into two groups: network-wide broadcasting and multicasting. In network-wide broadcasting the objective is to distribute the generated data to all the nodes in the network. The most basic network-wide broadcasting approach is simple flooding, where at each node the received data is retransmitted with the aim of reaching all nodes in a connected network.

There are several more efficient network-wide broadcasting schemes that increase the efficiency by reducing the number of redundant retransmissions and/or collisions. On the other hand, the objective of multicasting is to deliver the data to a subset of the nodes in the network. By using a data dissemination structure, multicasting protocols limit the diffusion of the data to a certain subset of the entire network, namely to the multicast members. The data dissemination scheme used in multicasting protocols range from tree based routing strategies where the redundant transmissions are eliminated to mesh-based routing strategies that cope with frequent link breakages by controlled addition of redundant links. The authors in and present recent surveys on various group communication protocols. There is additional overhead incurred in multicasting protocols compared to broadcasting protocols. In certain scenarios, the cost of collecting and processing the additional information overwhelms the gains in limiting the data dissemination structure to the multicast members. As one might expect, in scenarios where the majority of the nodes are part of the multicast group, one can increase the efficiency by using a broadcasting protocol instead of using a multicasting protocol. In this dissertation, our objective is to investigate the trade-offs between multicasting and broadcasting in order to determine the conditions that make one of them preferable over the other.

2) Group Communications in the TRACE Family of Protocols

The main purpose of this section is to give the reader insight into the differences between NB-TRACE and MC-TRACE. The details of the protocols, NB-TRACE and MC-

TRACE, can be found in references and, respectively. Both MC-TRACE and NB-TRACE are cross layer approaches where the MAC layer and the routing layer functionalities are implemented together in a unique framework. The MAC scheme of the protocols follows from MH-TRACE, where the network is organized into overlapping clusters, each managed by a clusterhead (CH).

3) NB-TRACE

Routing in NB-TRACE makes use of the clustering structure. The protocol sends a copy of each data packet to all of the CHs, and the CHs retransmit these packets to their cluster members. Each data session starts with an initial flooding stage where each rebroadcasting node implicitly acknowledges its upstream node through IS packets as a part of its transmission. In the case of the existence of more than one upstream node, only one of them is selected and announced in the downstream nodes IS packet.

A node drops its relaying status and stops retransmitting the packets when it does not receive an acknowledgement for a certain amount of time. Only the CHs keep retransmitting the packets even when they do not receive any downstream acknowledgement. This behavior prunes the redundant retransmissions and creates a tree that starts from the source node and ends at the CHs. Since the CHs form a dominating set, this ensures that 25 once all the CHs transmit the message, all nodes in the network will receive the message. The dynamic behavior of the network is handled by a local branch repair mechanism.

4) MC-TRACE

MC-TRACE implements multicast routing on top of MH-TRACE using a mixed layer approach. Like NB-TRACE, MC-TRACE also starts with an initial flooding stage. Nodes that do not receive a downstream acknowledgement stop retransmitting. However, in MC-TRACE, CHs do not take a special role in routing. Instead, the member nodes keep sending an acknowledgement to their upstream node even when they do not receive any downstream acknowledgements. Therefore, the tree is kept alive directly by the group members. Furthermore, in MC-TRACE, retransmitting nodes also choose and announce a downstream node in addition to their upstream node. The first node that sends an upstream acknowledgement is selected as the downstream node and announced in the following transmissions.

The node that is announced as the downstream node is responsible for sending upstream acknowledgements and keeping the branch alive. With the help of this mechanism, in the case of more than one leaf member node receiving the data from the same branch, only one of them sends the acknowledgement messages. Although this mechanism eliminates redundant acknowledgements, the need for acknowledgements from the leaf nodes makes MCTRACE consume considerably more resources compared to NB-TRACE when the multicast group members are spread throughout the region.

III. PROTOCOL DESIGN DESCRIPTION

The key challenges in effective MAC protocol design are the maximization of spatial reuse and providing support for non-uniform load distributions. Spatial reuse is tightly linked to the bandwidth efficiency. Due to the lossy nature of the propagation medium, the same channel resources can be used in spatially remote locations simultaneously without affecting each other. Incorporating spatial reuse into the MAC protocol drastically increases bandwidth efficiency. On the other hand, due to the dynamic behavior in MANETs, the traffic load may be highly non-uniform over the network area. Thus, it is crucial that the MAC protocol be able to efficiently handle spatially non-uniform traffic loads. Uncoordinated protocols intrinsically incorporate spatial reuse and adapt to the changes in load distribution through the carrier sensing mechanism. However, coordinated protocols require careful design at the MAC layer allowing the channel controllers toutilize spatial reuse and accommodate any changes in the traffic distribution.

Changes in the node distribution and packet generation patterns result in a non-uniform load distribution. Similar to cellular systems, coordinated MANET MAC protocols need specialized spatial reuse and channel borrowing mechanisms that address the unique characteristics of MANETs in order to provide as high bandwidth efficiency as their uncoordinated counterparts. Due to node mobility and the dynamic nature of the sources in a MANET, the network load oftentimes is not uniformly distributed. In this chapter, we propose two algorithms to cope with the non-uniform load distributions in MANETs:

- A light weight distributed dynamic channel allocation algorithm based on spectrum sensing, and
- A cooperative load balancing algorithm in which nodes select their channel access providers based on the availability of the resources.

We incorporate these two algorithms for managing non-uniform load distribution in MANETs into the MH-TRACE framework. Although MH-TRACE incorporates spatial reuse, it does not provide any channel borrowing or load balancing mechanisms and thus does not provide optimal support to dynamically changing conditions and non-uniform loads. Hence, we apply the dynamic channel allocation and cooperative load balancing algorithms to MH-TRACE, creating the new protocols of DCA-TRACE, CMH-TRACE and the combined CDCA-TRACE.

CDCA-TRACE is a novel MAC protocol that maintains the same energy efficiency and channel regulation principles of MH-TRACE while enabling dynamic and scalable channel assignment in addition to cooperative load balancing. Instead of message exchanges between the channel regulators (CHs), CDCA-TRACE utilizes spectrum sensing to keep track of channel usage in nearby clusters. This feature minimizes the overhead found in dynamic channel allocation schemes for cellular networks and makes CDCA-TRACE suitable for MANETs.

CDCA-TRACE also incorporates cooperation among the member nodes to improve the distribution of the load among the CHs and complements dynamic channel allocation to enhance the service rate. The contributions of the chapter are: i) we propose a light weight dynamic channel allocation scheme for cluster-based mobile ad hoc networks; ii) we propose a cooperative load balancing algorithm; iii) we incorporate these two algorithms into our the TRACE framework leading to DCA-TRACE and CMH-TRACE; and iv) we combine both algorithms leading to CDCA-TRACE that provides better support for non-uniform load distributions. We compare the performance of these algorithms for varying network loads.

A. Bandwidth Efficiency Techniques for Coordinated MAC Protocols

In this section we describe the lightweight dynamic channel allocation mechanisms based on channel sensing and the cooperative load balancing algorithms. We begin with a discussion of our assumptions:

- Single transceiver: The nodes in the network are equipped with a transceiver that can operate in one of two modes: transmission or reception. Nodes cannot simultaneously transmit and receive.
- Channel Sensing: The receiver node is able to detect the presence of a carrier signal and measure its power even for messages that cannot be decoded into a valid packet.
- Collisions: In the case of simultaneous transmissions in the system, neither of the packets can be received unless one of the transmissions captures the receiver. The receiver can be captured if the power level of one of the transmissions is significantly larger than the power level of all other simultaneous transmissions. Such a capturing mechanism is the driving factor of the advantages gained through channel reuse.
- Channel Coordinators: The channel resources are managed and distributed by channel coordinators. These coordinators can be ordinary nodes that are selected to perform the duty, or they can be specialized nodes. The channel is provided to the nodes in the network for their transmission needs by these channel coordinators. The system is also assumed to be a closed system where all the nodes comply with the channel access rules.

1) Dynamic Channel Allocation Algorithm

The first mechanism that we propose is a dynamic channel allocation (DCA) algorithm similar to the ones that exist in cellular systems. Under non-uniform loads, it is crucial for the MAC protocol to be flexible enough to let the unused bandwidth be allocated to the controllers in the heavily loaded region(s). Cellular systems usually handle channel allocation through message exchanges between the cell towers. However, these messages would be too costly for a MANET system due to the highly dynamic behavior of the network. Instead, we adopt a dynamic channel borrowing scheme that utilizes spectrum sensing.

In this algorithm, the channel controllers continuously monitor the power level in all the available channels in the network and assess the availability of the channels by comparing the measured power levels with a threshold. If local load increases beyond local capacity, provided that the measured power level is low enough, the channel coordinator starts using the channel with the lowest power level measurement. Once the channel coordinator starts using the channel, its transmission increases the power level measurement of that channel for nearby controllers, which in turn prevents them from accessing the same channel. Similarly, as the local network load decreases, controllers that do not need some channels stop the transmissions in that channel, making it available for other controllers.

In this dynamic channel allocation algorithm, channel coordinators react to the increasing local network load by increasing their share of bandwidth. Although being effective in providing support for non-uniform network loads, the reactive response taken by the channel coordinators increases the interference in the entire.

2) Cooperative Load Balancing

The DCA algorithm approaches the problem of non-uniform load distribution from the perspective of the channel coordinators. The same problem can also be approached from the perspective of ordinary nodes in the network. This cooperative behavior smooths out mild non-uniformities in the load distribution without the need for the adjustments at the channel coordinator side. The load on the channel coordinators originate from the demands of the ordinary nodes. Many nodes in a network have access to more than one channel coordinator. The underlying idea of the cooperative load balancing algorithm is that the active nodes can continuously monitor the channel usage and switch from heavily loaded coordinators to the ones with available resources. These nodes can detect that the channels available at the channel coordinator are depleted and shift their load to the channel coordinators with more available resources. The resources vacated by the nodes that switch can be used for other nodes that do not have access to any other channel coordinators. This increases the total number of nodes that access the channel and hence increases the throughput.

These internal and external agents are known as actors. So use case diagrams are consists of actors, use cases and their relationships. The diagram is used to model the system/subsystem of an application. A single use case diagram captures a particular functionality of a system. So to model the entire system numbers of use case diagrams are used.

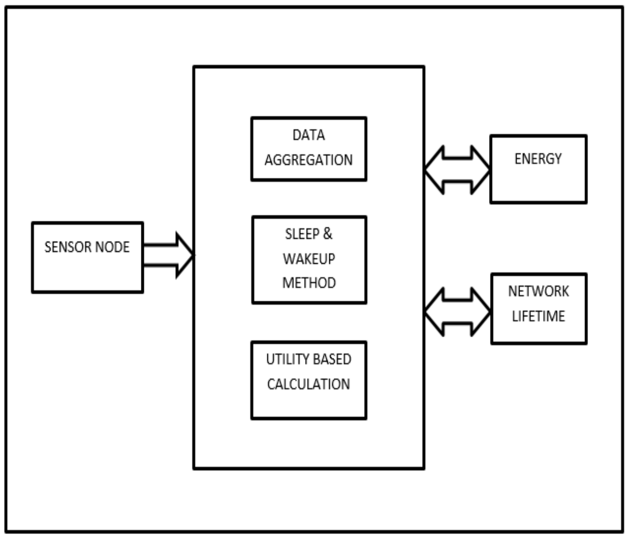

Fig 1 System architecture.

IV. CONCLUSION

In this project we have not investigated the effects of upper layers such as the routing layer, and instead focused on the MAC layer capability and local broadcasting service. Packet routing has a significant impact on the load distribution. Local link layer broadcasting service is directly used by some routing algorithms such as network flooding. Moreover, it can be used alongside with network coding and simultaneous transmission techniques for cooperative diversity. In general, joint optimization of the MAC and routing layers may enable even more efficient solutions. Investigation of the effects of routing is left as future work.

REFERENCES

[1]. T. Numanoglu, B. Tavli, and W. Heinzelman. An analysis of coordinated and non-coordinated medium access control protocols under channel noise. Military Communications Conference, 2005.MILCOM 2005. IEEE, pages 2642–2648 Vol. 4, Oct. 2005.

[2]. A. Chandra, V. Gummalla, and J. O. Limb. Wireless medium access control protocols. IEEE Communications Surveys and Tutorials, 3:2–15, 2000.

[3]. P. Mohapatra, J. Li, and C. Gui. Qos in mobile ad hoc networks. IEEE Wireless Communications Magazine, 10:44–52, 2003.

[4]. B. Tavli and W. B. Heinzelman. MH-TRACE: Multi hop time reservation using adaptive control for energy efficiency. IEEE Journal on Selected Areas of Communications, 22(5):942–953, June 2004.

[5]. T. Cooklev. Wireless Communication Standarts. IEEE Press, 2004.

[6]. J. Karaoguz. High-rate wireless personal area networks. Communications Magazine, IEEE, 39(12):96–102, Dec 2001.

[7]. T. Numanoglu, B. Tavli, and W. B. Heinzelman. The effects of channel errors on coordinated and non-coordinated medium access control protocols. In Proceedings of IEEE International Conference on Wireless and Mobile Computing, volume 1, pages 58–65, Aug 2005. 261.

[8]. Bora Karaoglu, TolgaNumanoglu, and Wendi Heinzelman. Analytical performance of soft clustering protocols. Ad Hoc Networks, 9(4):635 – 651, 2011.

[9]. Lifei Huang and Ten-Hwang Lai. On the scalability of ieee 802.11 ad hoc networks. In Proceedings of the 3rd ACM international symposium on Mobile ad hoc networking & computing, MobiHoc '02, pages 173–182, New York, NY, USA, 2002. ACM.