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Network-wide Broadcasting in Mobile Ad-hoc Networks

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Abstract

A Mobile Ad hoc Network (MANET) is an autonomous system of mobile nodes with routing capabilities connected by wireless links, the union of which forms a communication network modeled in the form of an arbitrary graph. The vision of Mobile Ad Hoc Network (MANET) is wireless internet, where users can move anywhere anytime and still remaining connected with the rest of the world. The main challenges in MANET are reliability, bandwidth and energy consumption. Broadcasting is the process in which a source node sends a message to all other nodes in MANET. Network wide broadcasting in Mobile Ad Hoc Network provides important control and route establishment functionality for a number of unicast and multicast protocols. Broadcasting in MANET poses more challenges than in wired networks due to node mobility and scarce system resources. Broadcasting a packet to the entire network is a basic operation and has extensive applications in mobile ad hoc networks (MANETs). This paper presents multi rate network wide broadcasting by using superposed coding and find out throughput, packet delay and energy consumption in a MANET.

IndexTerms— MANET, Multi rate, broadcasting, superposed coding, wireless network

Introduction

In a mobile ad-hoc network (MANET), mobile units can communicate with each other directly via wireless links in the absence of a fixed wired infrastructure [1, 2]. MANET is different from a wireless mobile network which usually consists of a static wired part, in which fixed hosts and base stations are interconnected through a high speed wired network, and a mobile wireless part, in which mobile units communicate with the base stations through wireless connections. A base station can only communicate with the mobile units moving within its coverage area called cell. Mobile units can communicate with each other only through at least one base station. Mobile units run on batteries while base stations are supplied by stable system power from static networks. In MANET, every mobile unit can move freely and communicate directly with another mobile unit as long as that mobile unit is in its communication coverage area.

In a mobile computing environment, bandwidth and power limitations impose significant restrictions on data management [3]. These limitations require frequent disconnection and inspire the need for energy-efficient data access methods. While research in mobile computing has received growing interest in recent years due to the large number of potential applications, research in mobile ad-hoc network is still in its infancy.

Data broadcasting is considered as a main method of information dissemination in mobile wireless networks and can also be adopted for information distribution in mobile ad-hoc networks.

For broadcast transmissions, the capacities of the communication links from the source to the intended recipients vary greatly due to differences in communication range, fading, and interference on these links. Therefore, it is crucial to explore the characteristics of the broadcast channel that can be utilized to improve the throughput of the network [4].

Due to differences in qualities of the links between a broadcasting source node and the intended recipients, it is advantageous to adjust the transmission scheme for broadcasting data so that a single transmission can be best received at all receivers. In other words, with a single transmission, the nodes with \high quality" links receive \high rate" information whereas the nodes with \low quality" links receive \low rate" information. This multi-rate broadcasting can be achieved by using Cover's theory of superposed information [4,5].

Superposed Coding

According to the channel coding theorem, any transmission rate R may be achieved by employing a customary code [68]. The theory states that each one rates below capacity C are achievable, that is, for each and rate $R < C$, there exists a sequence of $(2^{nR}, n)$ codes with most chance of error, for n sufficiently large. This coding makes positive that, with high chance, channel noise won't cause errors within the decoding method. The thought of superposed coding is to feature further coding on high of the primary coding in such the way that already separated code words are displaced once more per new data. The second displacement is smaller than the primary one, and it's unlikely to be decoded by any receiver with a poor channel. However, any receivers with an honest channel are going to be able to decode each the primary and also the second displacements of the code words. Therefore, nodes with poor channels decode only the lower rate data (i.e., the primary displacement of the code words) whereas nodes with smart channels decode each the lower rate and also the further data. This method is visualized in figure.1

Note that introducing further data to the code words can create them a lot of vulnerable to channel errors, since the new distance between the code words is smaller than it'd be if we have a tendency to coded solely the lower rate data. On the opposite hand, Cover proved that degradation within the rate for the poor channel can enable a lot of rewarding increase within the rate for the great channel. Bergmans proved that the set of rates achieved by this system defines the higher limit for a broadcast channel.

We demonstrate the thought of superposed coding by employing a straightforward binary pulse amplitude modulation (BPAM) constellation to represent the low rate data. In order to superpose the high rate data we have a tendency to rework the binary PAM constellation into no uniform quadrature amplitude modulation (QAM). Figure.2 illustrates the error regions and totally different noise margins, d1 and d2, for the low rate and extra data, respectively. Note that these regions and margins correspond to the chosen symbol. The no uniform spacing makes it a lot of easier for a receiver to properly recover the low rate data (first bit) than the extra data (second bit). Therefore, the primary bit will be decoded by all receivers inside the transmission vary of the supply, whereas the second bit conveys the extra data that may solely be recovered by receivers with sensible channels. During this method, we have a tendency to simultaneously send 2 packets employing a single transmission and supply 2 totally different rates of broadcasting, which potentially could result in doubled link throughput. Using non-uniform QAM as shown in Fig. 3 will increase the transmit energy per symbol from units to units.

On the other hand, if we assume that the energy per symbol is kept constant at units we get the following relationship between $d_{1,}$ d_2 and;

Eqn. 2 tells us that as d_2 will increase d_1 should decrease to make amends for the extra energy required for increasing further data coverage. This may end in a reduced vary of transmission and hence, reduced connectivity of the network. Note that this instance will be simply extended to produce quite 2 levels of superposed information.

We have determined the number of increase within the transmit energy in terms of noise margins within the constellation diagram. However, so as to work out the number of transmit energy required to produce multi-rate availability at a definite distance we've got to look at the propagation model. The propagation model determines the trail loss along a link and conjointly the effective coverage space of a transmitter. In MANET's, the complexity of signal propagation makes it troublesome to get a single model that characterizes path loss accurately for various environments. When tight system specifications should be met, correct path loss models will be obtained from complex analytical models or empirical measurements [6]. However, for our general tradeoff analysis, we tend to use a straightforward model that captures the essence of signal propagation without resorting to sophisticated path loss models that are solely approximations to the real channel anyway. We tend to use a hybrid model that consists of the free area and also the two-ray ground reflection models. Fries presented the subsequent equation to calculate the propagation loss in free area at a distance r from the transmitter.

Where "s is that the transmit energy per image, G_t and G_r are the antenna gains of the transmitter and also the receiver, respectively, L (L 1) is that the system loss, and is that the wavelength. In our simulations we have a tendency to set $G_t = G_r = 1$ and L = 1. This model considers the communication vary as a circle round the transmitter. At long distances, the Friis model provides less correct prediction of the received signal strength compared with the two-ray ground reflection model that considers both the direct path and a ground reflection path.

Where h_t and h_r are the heights of the transmit and receive antennas, respectively. To be according to the free house model, we have a tendency to once more set $G_t = G_r$ = one and L = 1.

Eqn. 4 shows a faster propagation loss than Eqn. 3 as distance will increase. However, the two-ray model doesn't give a correct estimation of received energy per image for brief distances thanks to the oscillation caused by the constructive and destructive combination of the 2 rays. Instead, the free

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house model ought to be used when d is tiny. Therefore, a cross-over distance r_c is calculated within the hybrid model.. When r <r_c Eqn. 3 is employed to predict receive signal strength, and when r >r_c, Eqn. 4 is used. This cross-over distance, r_c, calculated as,

(5)

Using Eqn. 5 and also the modulation theme shown in Figure four.3, for a fixed single rate transmission radius R_1 = 250m we will calculate the quantity of extra energy per image required to introduce the aforementioned multi-rate modulation scheme. With R1 constant and utilizing the connection in Eqn. 1, we have a tendency to plot the percentage increase within the transmit energy per image required to produce multi-rate coverage R_2 (see Fig. 3). This figure illustrates what quantity additional energy per image we tend to require to hide a bigger region where nodes receive each the low and extra rate info (i.e., the high-rate info as we tend to decision during this paper). Figure 4 illustrates the two regions where totally different rates are offered. These figures will be used to determine the quantity of additional energy per image required for a multi-rate broadcasting system, where the multi-rate coverage space is of the utmost importance.

On the opposite hand, if we want to stay the initial energy per image constant, we have to verify the quantity of energy to dedicate to every rate (i.e., low-rate and extra rate). Figure 5 illustrates the energy per image distribution between the 2 rates achieved through non-uniform QAM modulation.

We tend to assume that is that the initial transmit energy per image that's required to produce a 250mtransmission radius for the traditional single-rate broadcasting state of affairs that employs binary PAM. the worth of is kept constant, and at the intersection purpose of the curves, where R_1 = R_2, this energy per image is shared between the 2 rates of the transmission. At now the modulation theme becomes regular QAM and isn't any longer non-uniform as depicted in Figure 2.

It is additionally fascinating to ascertain how the mounted transmit energy per image is shared between the two rates as we tend to increase the coverage of the extra rate transmission.

As R_2 will increase, the coverage for extra rate data willincrease, while the amount of energy used for low-rate data decreases, and hence R_1 decreases. Increasing R_2.As cowl showed to the globe, we've got confirmed that with a little sacrifice from the low-rate coverage, we are going to be ready to have a drastic increase in the high-rate transmission radius R2. At the purpose where half the initial transmit energy per image has been sacrificed, we've got equal coverage of » 195m for each rates. This is a right away result of the quadratic relationship between the energy per image and the noise margins (Eqn. 1). Note that Figure 5 was generated using the hybrid propagation model and Eqn. 2. However, this relationship is simply derived for any channel propagation model. Our study is motivated by these already proven capabilities of multi-rate broadcasting and additionally by the actual fact that these ideas haven't been utilized in a very multicasting scenario before. Within the remainder of this chapter, we tend to discuss our plan of mixing multi-rate broadcasting with multi-hop routing, providing multi-rate network-wide broadcasting and multi-rate multicasting. We tend to show the advance this integration can bring to a multi-hop network.

Constellation Diagram Design In Multi-Rate Multicasting

In this study, we have a tendency to use a two-level multi-rate multicasting situation. However, the main plan of multi-rate multicasting needn't be restricted to 2 levels. numerous non uniform constellations is designed to increase this idea to a lot of levels, which, coupled with scalable coding, provides even a lot of flexibility and decisions to the multicast members. In this section we offer more insight into superposed coding. We have a tendency to begin with a Binary Pulse Amplitude Modulation (BPAM) constellation and modify this according to Cover’s pointers presented in his paper concerning broadcast channels. Figure 6 shows the easy constellation diagram of BPAM. Figure 7 shows the non-uniform Quadrature Amplitude Modulation (QAM) constellation that is obtained by assigning a smaller displacement to the quadrature part than the in-phase part within the BPAM constellation. This will be thought of as each non-uniform QAM or non-uniform QPSK. As we have a tendency to mention earlier, uneven distribution of constellation points results in completely different noise margins for the bits encoded during a transmitted image.

We can further use this concept to introduce several levels of noise margins. Figure 8 shows a non uniform 16-ary QAM constellation, that provides four totally different noise margins for the encoded four bits of knowledge per image. If we have a tendency to assume once more that the propagation loss mainly depends on distance, we've four totally different penetration distances for these bits. In alternative words, there are four regions during which the transmitted image will be decoded at four totally different rates. Sun et al., utilize a special case of the non-uniform 16-ary QAM constellation in achieving a versatile unequal error protection. Figure 9 illustrates a sixty four purpose non-uniform constellation that utilizes additional decoding regions when

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totally different rates are required. Adjusting the distribution of the symbols in a non-uniform M-ary constellation will be determined consistent with many style parameters. Density of the network, network boundaries, power limitations, mobility patterns, antenna sort, and necessities of the applying will be listed as a number of the numerous factors which will have an effect on the constellation diagram style. During this thesis, we have a tendency to utilize the non-uniform QAM (non-uniform QPSK) constellation to realize 2 completely different rates at 2 different distances to realize multi-rate multicasting.

Multi-Rate Network-Wide Broadcasting

After explaining each the thought of superposed coding and therefore the NB-TRACE protocol, we tend to currently mix these techniques to realize multi-rate network-wide

Broadcasting, nodes that have prime quality links with the supply node will rebroadcast the superposed low rate and extra info combine. On the opposite hand, any node with a coffee quality link with the supply node cannot decode the extra info therefore it has to rebroadcast solely the low rate info. There's additionally a 3rd case within which nodes receive each low rate and extra info through completely methods with different delays. This availability permits the nodes to determine whether or not they wish to receive packets with low rate and low delay or high rate with higher delay (high rate knowledge comes through shorter hops and so additional hops, which ends up in higher delay). Note that, for simplicity we tend to assume there are solely 2 states for a given link. However, as one will increase the amount of levels in superposed coding, the amount of link quality levels can increase accordingly.

We propose that one among the foremost effective ways in which of exploiting the multi-rate info availability is to use scalable supply coding and create full use of the entire available rate at when instant. Scalable supply coding is essentially a hierarchical coding theme, where coarser representations are embedded into finer ones, thereby allowing access to the supply at a range of resolutions. Rimoldi generalized the scalable supply coding drawback and discovered necessary and sufficient conditions for the achievability of any sequence of rates and distortions. Scalable supply coding is often employed in wireless communication applications where the accessible communication rate is time-varying. However, at a given time throughout a transmission there's solely a certain rate of data accessible, that is decided by the accessible communication rate. In different words, though the published info rate is variable after we employ scalable supply coding, there's solely one transmission rate at a given time. On the opposite hand, after we mix multi-rate transmission with scalable coding during a MANET, nodes with completely link qualities can have different rates accessible to them instead of one rate that varies in keeping with supply coding.

Table 1. Simulation Setup

Parameter	Value
Number of Nodes	256
Simulation Area	1000m X 1000m
Simulation Time	100s
Transmission Ranges (Low-High)	(150m-250m)
Number of Repetitions	5
Node Mobility	Random Way-Point

Multi-Rate Network-Wide Broadcasting Simulations

In this section, we wish to analyze each ends of the delay vs. throughput (quality) trade-off by using NB-TRACE and Flooding with IEEE 802.11. Table 1 summarizes the simulation setup we tend to used to analyze these architectures. We tend to performed 2 sets of simulations where every set contains a totally different priority. First, we tend to prioritize the reception of the packets with lowest delay. This results in a quicker network-wide broadcasting and mainly the low rate traffic is forwarded by the nodes. Within the second set of simulations, throughput is that the priority for the nodes, that therefore ought to forward the high rate traffic. All the nodes receive each the low rate and also the extra info whereas compromising the delay since the high rate info will solely be recovered by the nodes within R2 as shown in Figure 4. These 2 extreme priorities help us to demonstrate the limits and capabilities of superposed coding on network-wide broadcasting. Note that in each eventuality, the supply node broadcasting is that the same, however, which nodes rebroadcast and also the rates they use for rebroadcasting modification looking on the priorities.

We simulated conversational voice coded at 2 totally different rates, particularly the low rate (13Kbps) and also the high rate (26Kbps). The high rate corresponds to 2 (superposed) voice packets per super frame and might be decoded by nodes among R1 = 150m, whereas the low rate corresponds to 1 voice packet per super frame and might be decoded by nodes among R_2 = 250m. The channel rate is ready to two Mbps and also the customary IEEE 802.11 physical layer is utilized for each architecture.

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Table 2. Simulation parameters

Acronym	Description	Value
N_C	Number of cont. slots per frame	15
N/A	Header Packet Size	36B
N_{DS}	Number of data slots per frame	14
N_F	Number of Frames	7
N/A	Data Packet Size	110B
D_{CS}	Carrier Sense Range	507m
T_{VF}	Voice Packet Generation Period	61.5ms
T_{di}	(@ Intermediate Nodes)	250.0ms
T_{ds}	Packet Drop Threshold (@ Source Node)	61.5ms
N/A	All other control packet size	10B
T_{SF}	Super frame duration	61.5ms
D_{CS}	Carrier Sense Range	507m

All the simulations arerun with 256 nodes, moving inside a one km by one km space for one hundred seconds in line with the Random Way-Point (RWP) mobility model with node speeds chosen from a regular distribution between zero.0 m/s and five.0 m/s. The supply node is stationary and located in the middle of the network. Acronyms, descriptions and values of the parameters used in the simulations are presented in Table 2.

A. Throughput and Packet Delay

The throughput results are given in terms of average Packet Delivery Ratios (PDRs) of both architectures in Table III. Table IV presents the typical packet delay and delay jitter values. The quantity of knowledge packets received by any node aside from the supply node are averaged and divided by the entire variety of knowledge packets broadcasted by the source node to obtain the typical PDRs. PDRs of each NB-TRACE and Flooding with IEEE 802.11 are on top of ninety nine when the priority is low delay. However, when the priority is throughput IEEE 802.11 PDR decreases (less than 90%) thanks to the rise in the traffic. Note that although the PDR decreases, the entire throughput will increase (88% of twenty six Kbps is quite ninety nine of thirteen Kbps).

Table 3 Packet delivery ratios (pdrs) according to the two priorities: delay and throughput

Architecture	Packet Delivery Ration (Delay)	Packet Delivery Ratio (Throughput)
Flooding (IEEE 802.11)	99.5% 99.4 (min)	88.1% 84.3(min)
NB-TRACE	99.6% 99.2% (min)	99.4% 97.7% (min)

In the high throughput case, nodes are forced to receive and rebroadcast high rate information so as to realize high throughput. High rate data contains vary of 150m, 100m but low rate data. This ends up in a smaller communication radius and an increased range of rebroadcasting nodes. Therefore, the number of traffic needed to realize network-wide broadcasting will increase, that causes the performance drop in Flooding with IEEE 802.11. On the opposite hand, increased traffic brings the availability of high rate data for all the nodes within the network. Actually, the

Through put of the network is nearly doubled for NB-TRACE even supposing the PDR value stays nearly constant. This can be just because the high rate packets have twice as much data because the low rate packets.

Table 4. Packet delay and delay jitter according to the two priorities: delay and throughput

Architecture	Packet Delay & Delay Jitter (Delay)	Packet Delay & Delay Jitter (Throughput)
Flooding(IEEE 802.11)	12.3 ms, 63.7ms	41.1 ms, 69.6ms (jitter)
NB-TRACE	61.0ms, 10.6 ms(Jitter)	192.9ms, 10.9 ms(Jitter)

When we impose delay as a constraint on packet forwarding, solely a fraction of nodes within the network receive high rate packets that are broadcasted by the supply node. Other nodes are forced to receive low rate packets, that have lower delay values, since they propagate through the network faster (i.e., rather than waiting to recover the high rate data, nodes need to settle with lower delay, low rate information). On the other hand, having throughput because the priority forces nodes to attend for multi-rate broadcast by intermediate nodes that are shut enough to the supply node located within the middle of the simulation space.

This will increase the packet delay since the packets are propagated throughout the network with a smaller effective radius of communication, which is 150m rather than 250m during this case. In NB-TRACE, knowledge packet transmissions are coordinated by cluster heads and knowledge slots become accessible with the amount TSF. This cyclic frame structure leads to higher delay values for NB-TRACE. Flooding with IEEE 802.11 has lower delay values since IEEE 802.11 permits nodes to transmit whenever the channel is obtainable. On the opposite hand, NB-TRACE jitter is a smaller amount than 16% of IEEE 802.11 jitter in each case attributable to the automated renewal of the channel

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access that reduces the variation within the interarrival times of knowledge packets. In fact, low jitter is that the most vital QoS parameter in multimedia communications.

B. Energy Consumption

One of the foremost vital benefits of NB-TRACE over Flooding with IEEE 802.11 is its higher energy potency. Average energy dissipation per second for NB-TRACE and Flooding with IEEE 802.11 with 256 nodes as perform of packet forwarding priority is presented in Table V. NB-TRACE energy dissipations each beneath lower delay and high throughput priorities are but 2 hundredth of the energy dissipation of Flooding with IEEE 802.11. Yet, the energy dissipation of NB-TRACE is higher when the priority is higher throughput, which is anticipated as a result of the number of traffic is doubled. Furthermore, a lot of hops are needed to achieve outer nodes of the network and consequently a lot of nodes are concerned in the rebroadcasting method, hence fewer nodes will keep within the sleep mode. Flooding with IEEE 802.11 energy dissipation doesn't show any important modification when we modification the packet forwarding priority attributable to the actual fact that flooding already engages all nodes within the network to rebroadcast all knowledge packets. The sole distinction is in transmission where virtually Bastille Day a lot of power is required when forwarding the high rate data than is required for flooding simply the low rate data. These results facilitate us perceive what we tend to are trading off so as to double our throughput (by receiving each the low rate and therefore the further information). The two extreme constraints on packet forwarding presented during this section ought to sure any result that's obtained by using this mixture of delay and throughput constraints.

Table 5. Energy consumption according to the two priorities: delay and throughput

Architecture	**Energy Consumption (Delay)**	**Energy Consumption (Throughput)**
Flooding(IEEE 802.11)	237.3mJ/s	240.1mJ/s
NB-TRACE	35.2 mJ/s	48.5 mJ/s

Conclusion

We tend to believe that multi-rate multicasting can offer an economical resolution to satisfying the various wants of these devices through one multicast transmission, thereby reducing energy dissipation and bandwidth usage. Superposed coding makes different information rates simultaneously available, and this lets nodes decide which set of upstream nodes they need to listen to in order to maximize the overall ratio of data rate/delay and minimize the energy consumption. We conclude that this multi-rate broadcasting scheme should prove more efficient in a multi-casting scenario where nodes with different throughput requirements and delay constraints can freely choose one of the available rates.

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