ON THE PERFORMANCE OF UNLICENSED DATA ACCESS SYSTEMS

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ABSTRACT

Unlicensed operation has become a viable alternative for building wireless access infrastructures. In the future unlicensed operation may be an important part of the infrastructure. However even if many problems can be solved there are many challenges involved as well.

This paper studies how two operators interact when they have two networks in the same geographical area. Data traffic (packets) is studied for two frequency hopping systems under different conditions. Different propagation, user requirements and for different amounts of available spectrum.

The outcome is highly situation dependent. This study does not find a technical solution that is better than splitting the spectrum. However unlicensed operation may have other benefits than the technical characteristics that makes it a candidate for future wireless systems.

INTRODUCTION

There are a number of trends that can be distinguished in the development towards 4th generation wireless systems. One trend is the increasing number of firms providing access services. Not only traditional infrastructure operators are expected to provide access services, but also municipalities, building owners and universities may also provide access to fixed networks[1].

Another trend is an increasing number of offered services requiring higher data rates. The cost of transferring a bit in cellular systems for a given system design tends to be inversely proportional to the available bandwidth[2]. Thus if a given amount of bandwidth is available the cost per bit tends to be constant. At the same time as the data rate requirements of services increase users are not willing to pay more for new services.

These trends result in an increased demand for bandwidth. The traditional way of assigning frequency spectrum to operators have been to give out licenses that give an operator the exclusive use of a frequency band in a specified geographical area[3]. However the most efficient way of utilising the available radio spectrum may not be to use licensing especially when considering other factors than pure technical performance. Unlicensed operation has been proposed as an alternative method for sharing the radio spectrum.

This paper compares the efficiency of unlicensed operation and traditional licensed spectrum sharing. The efficiency is measured as the cost of providing a user with a bit. We use a simplified model and let the infrastructure cost be proportional to the number of access points.

Devices operating in an unlicensed frequency band usually experience a lot of interference. Little is known about this interference and it cannot be controlled. It is not exactly clear which access method that performs the best in this type of environment. Wireless LAN standards that are under development use DS-CDMA (IEEE 802.11) [6], Dynamic channel assignment (Hiperlan/2) [7] or frequency hopping (Bluetooth) [8]. Frequency hopping has shown properties that are positive in a coexistence perspective [9]. That type of multiple access scheme will be investigated further here, but with a different traffic type.

SYSTEM MODEL

The performance of a system is better when a system is alone in a geographical area than when there are many systems in the same region that create interference. We model two systems that are located in the same area. The layout of access points for each system is described by a hexagonal layout.

If a piece of spectrum is split in half and all other system parameters are the same the system will be able to carry less than half of the traffic. This is known as trunking losses. In order to be able to compare the systems with different available bandwidth we need to use a traffic model that correctly includes the effect of trunking losses. We use a model for packet traffic that utilises a self-similar process for packet arrivals[4]. It was originally developed for modelling www traffic in a fixed network, but it has also been used for modelling mobile data traffic.

The users are spread over the service area according to a 2D-possion process. Each user has a number of communication sessions. The interarrival times of sessions are exponentially distributed, i.e. the session arrival process is a Poisson process. By varying the intensity different load conditions are created. The number of users on a cell is on the average half the number of available channels in the system. This relatively high number of users in a cell ensures that capacity limitations result from interference and not the (limited) radio link speed of the individual users. All users belonging to one operator has the same session arrival intensity. However the arrival intensity may differ between the two operators.

The number of packets within a session is binomial distributed with an average of 10 packets per session. The length of the packets is lognormally distributed with an average of 40 kbit and a variance of 120 kbit. The packet length is truncated at 480 kbit to avoid too large packets. The interarrival time of the packets within a session is Pareto distributed. with mean 5.04 seconds and alpha 1.2. The distribution is truncated at 333 seconds.

We choose a propagation model that models a campus area. The pathloss between users and access points is modelled as a distance dependent component and a log-normal random component[5]. In this case the systems will cause a lot of interference to each other. This forms a good framework for comparing unlicensed and licensed operation.

SYSTEM DESIGN

The frequency hopping system is using constant output power. The hopping sequence is random with a uniform probability of picking a channel in one slot. However the hopping sequences among users connected to the same base station are orthogonal. We also assume that all base stations are synchronised.

The basic data rate is set to 10 kbit/s. The timeslots are 200 ms long. There are two reasons for picking these parameters. The model is calibrated for channel rates of this order since it was originally for data traffic within GSM networks. The timeslots are made relatively long for a pragmatic reason. To ease the requires time for doing computational experiments. A frame is considered to be received correctly if the carrier to interference ratio is above 11 dB. Frames that are lost are retransmitted by using an ARQ scheme. Perfect acknowledgement is assumed. However if there are more than 10 consecutive errors the packet is dropped.

Since most of the traffic in future systems is expected to be downlink traffic we study only the downlink direction. However the studies could easily be extendet to take care of the uplink as well.

PERFORMANCE MEASURES

The average throughput for each user is measured as by determining how long the user has been active, either waiting to transmit a packet, transmitting or retransmitting frames. The number of total transmitted bits is then divided by the total active time.

Users are considered to be satisified if they have an average transmission rate above 50% of the raw link capacity, which in this case gives us a requirement of 5 kbit/s. The requirement on the system is that more than 95% of the users should be satisfied.

We measure the percentage of satisfied users in a number of load combinations for the two operators. This makes it possible for us to determine under which load combinations the two systems comply with the requirements.

NUMERICAL RESULTS

We study how the number of available channels influence the system performance. In figure 1 the results are presented. More channels usually result in higher capacity. However since the number of users in the system is proportional to the number of channels available the traffic will also increase as the number of channels increase.

However from an increased amount of channels we would also expect to see higher trunking efficiencies. But the traffic is modeled as a self-similar process which means that the “burstiness” will be maintained in aggregated data streams. Thus there are no large trunking gains when the number of channels increase.

We can see that the border of the feasible region is almost straight. Thus the total available capacity is not reduced when it is shared between two operators. This result is consistent with previous results for voice type traffic [9].

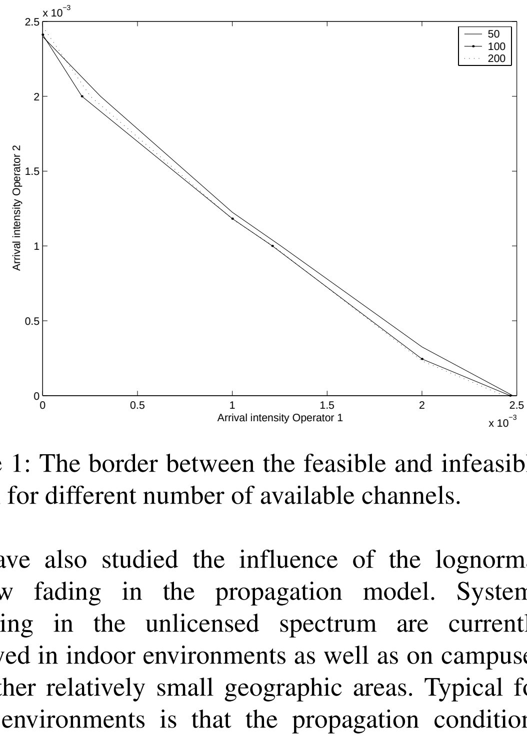

Figure 1: The border between the feasible and infeasible region for different number of available channels.

We have also studied the influence of the lognormal shadow fading in the propagation model. Systems operating in the unlicensed spectrum are currently deployed in indoor environments as well as on campuses and other relatively small geographic areas. Typical for these environments is that the propagation conditions differ from the environment current cellular systems are deployed in.

To understand how the environment influences the sharing characteristics we vary the amount of lognormal shadowfading to get a crude method of modeling different environments.

In figure 2 we can se that the system performance degrades when the amount of shadow fading increases. This is consistent with the experience from cellular systems. The reason is that the carrier strength has a larger variance and thus there are more users with low signal strength.

However the sharing characteristics seems to improve. The border becomes straighter as the shadow-fading increases. The reason is that the users far away from their own base station and close to a base station of the other operator experiences quite a lot of interference. However as the shadow fading increases the probability of beeing "lucky" and get a high pathloss to the other base station increases even though the base station is close in geographical terms.

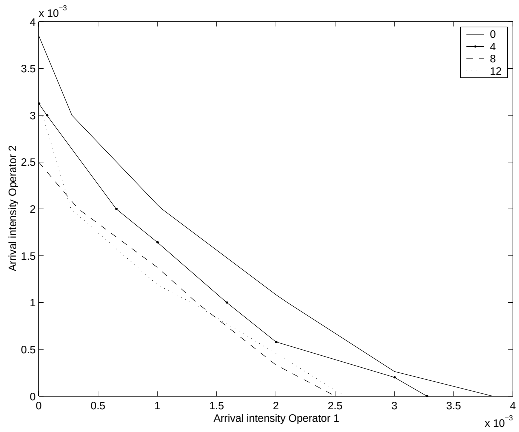

Figure 2: The influence of lognormal shadow fading on the amount of traffic that the systems can handle. 100 channels are available in the example.

We also study the influence of the throughput requirements on the coexistence properties. In figure 3 we see the results where the user requirement is that the datarate is at least 10% of the maximum possible (solid line) and 50% dotted line.

Of course it is possible to operate at higher loads, even if there are lots of retransmissions the packets will eventually get through.

However it is interesting to see that the shape of the curves are different. When the user requirement is at least 50% of the maximum datarate the available capacity is shared between the two operators and the total available capacity is approximately constant. But when the requirement is only 10% the total available capacity actually decreases when both operators have traffic.

The reason is probably that when both operators are active the "bad areas" where there is a lot of interference becomes more numerous. Thus more users have problem communicating. This effect is present if user requirements are higher as well, but since the traffic load is not as high the problem with bad areas does not become as pronounced.

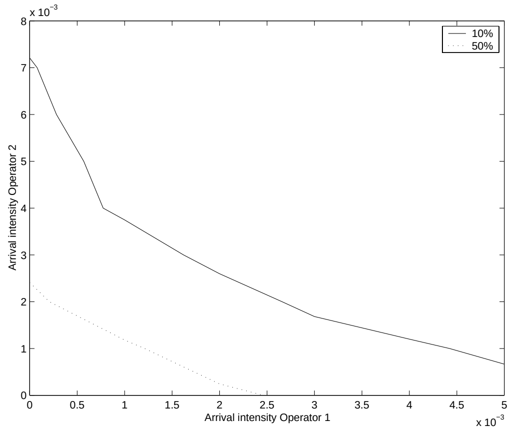

Figure 3: Influence of the requirements for satisfied users. To be satisfied a user needs to have an average datarate of at least 10% of the raw link capacity (solid line) or 50% dotted line. 100 channels.

CONCLUSIONS

Frequency hopping used in unlicensed settings can provide a viable solution for combating interference. However there are many cases where the available capacity is reduced by sharing the spectrum among operators.

From a technical perspective sharing spectrum may not be the best situation when designing radio access systems. However unlicensed operation has a number of other positive characteristics that may make it a viable solution even though the solution is not the best one from a technical perspective.

Finally we can conclude that the radio propagation environment affects the coexistence properties. It is not only the available capacity when one operator is alone that changes, but also the available capacity when the radio resource is shared. We have also seen that the quality requirements affect the coexistence properties.

This indicates that the coexistence properties are dependent on a number of variables and the relations may be quite complex. Thus it may be hard to create results that can easily be generalised.

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