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Title: **Frequency Sharing Rules for HIPERLAN- / U-NII- Systems**

Agenda item:

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Decision	
Discussion	X
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1 Cover note

This contribution is a copy of a paper with the same title submitted and accepted to the ACTS Mobile Summit 1997.

2 Abstract

HIPERLAN- and U-NII-systems are expected to work in unlicensed spectrum in the 5 GHz band. Several different types of systems will be allowed to operate within this spectrum. In order to allow different systems to work on the same frequencies, frequency sharing rules have to be applied. In this paper we discuss different options for sharing rules, their impact on different types of systems and define requirements on them for operation of systems guaranteeing Quality of Service to the user.

3 Introduction

Frequency in general is a rare resource. Frequencies of interest for digital wireless communication are somewhere in the range of 500 MHz and 60 GHz. The lower the frequency the better the propagation conditions and the more limited is the spectrum. In this paper we focus on broadband wireless communication systems with bandwidth requirements of about 25 MHz per frequency channel. Therefore, the frequencies of interest are limited to the range between 2 and 60 GHz. Furthermore, we focus on low-cost, mass market products, but radio equipment for frequencies higher than 20 GHz is too expensive at the moment for those kinds of applications. The systems we look at are HIPERLAN (HIgh PErformance Radio Local Area Network) [1] or U-NII (Unlicensed-National Information Infrastructure) type systems. Due to the decision of the FCC (Federal Communications Commission) [2] to allocate 300 MHz of spectrum in the 5 GHz band for U-NII type systems, we expect a similar amount of spectrum to be allocated in Europe and even world-wide. The FCC has not specified any frequency sharing rules for the allocated spectrum, although the systems allowed to operate there are not specified yet. FCC expects industry to develop suitable sharing rules. In this paper we discuss the advantages and disadvantages of different possible sharing rules as well as explain our choice of rules to be applied.

4 Basic assumptions

First of all we will give definitions for commonly used terms:

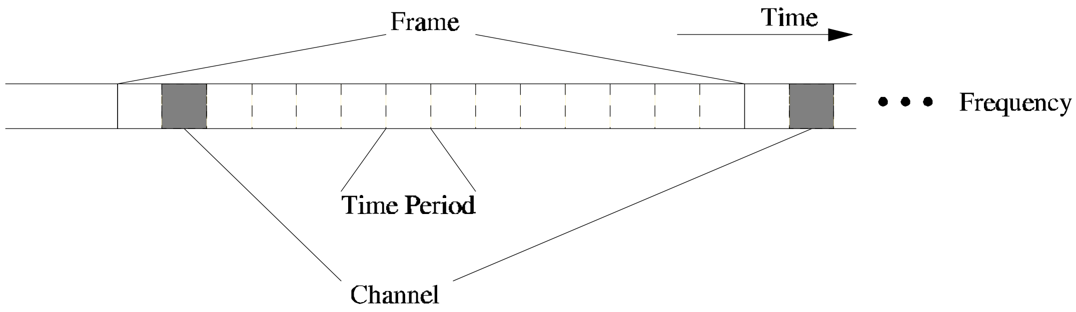

Figure 1: Definition of a channel

channel: In general, a channel is a piece of frequency and time. Frequency channels of a certain bandwidth are probably divided into time periods of a fixed length. Certain time periods are combined to a frame. This frame is repeated over the time. Therefore, a channel is a certain time period on a certain frequency repeated in time.

system: A system is the set of stations running the same protocol independent of their geographical position.

domain: A domain is the set of stations of the same system willing to communicate with each other.

Furthermore, we focus on sharing rules which are appropriate for the situation where in comparison with the total number of channels the number of different domains in one place is low.

Rules presented in this paper are used to guarantee systems to be able to work without disturbance rather than guarantee fair bandwidth sharing. Our rules just guarantee fairness in terms of first access, after that we propose a 'winner takes it all' rule.

Sharing rules within the same system are outside the scope of this paper, even if there are competing domains of the same system. The reason is that within a system it should be possible to exchange information and to implement protocols to share the resources in a fair way. This is related with dynamic channel allocation (DCA). In this case fairness is defined by the system producer rather than by the regulator.

We differentiate two types of systems: reservation based and non-reservation based system.

Reservation based systems:

This type of system is characterised by a master-slave access protocol which means that a master controls and regulates the channel access of all stations within one domain. Stations are only allowed to access the channel after capacity assignment by the master. Besides this reservation based mode of operation, random access is still needed for terminal registration, but may also be used for other purposes such as signalling depending on the protocol. But still random access is announced by the master in a reservation based system.

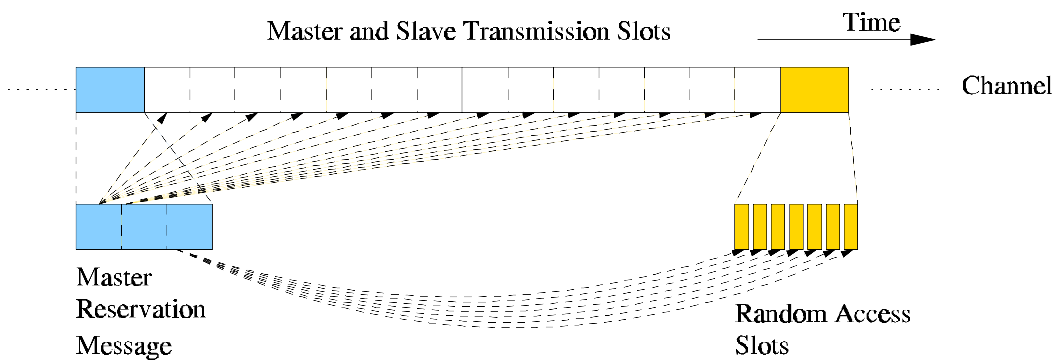

Figure 2: Structure of a master-slave type access protocol

Non-reservation based systems:

This type of system is characterised by a random access protocol. These systems use some kind of a CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) or LBT (Listen Before Talk) protocol. These protocols are enhanced in order to lower the probability of collisions. Nevertheless, in this kind of systems there is no controlled channel access and therefore the channel access is of a random kind.

5 The hidden station problem

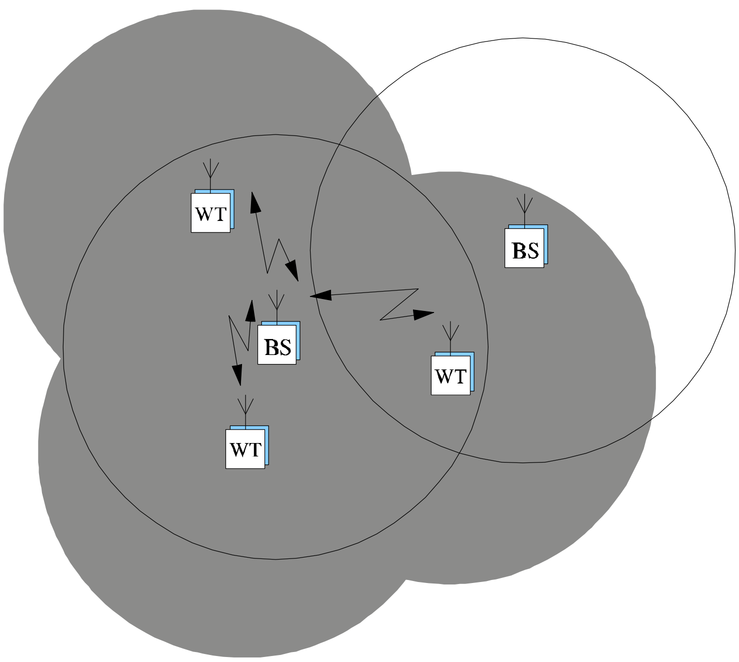

Figure 3: Hidden station approach in a cellular environment

Both, reservation based and non-reservation based systems face the problem of the hidden station approach. For non-reservation based systems this phenomenon is well known and addressed in literature, but dealing with frequency sharing rules, hidden stations are a severe problem for reservation based systems. In reservation based systems the master builds up a radio cell. This is done in a dynamic and flexible way, because no frequency planning can be used for HIPERLAN- / U-NII- systems. Furthermore, it might not be possible to establish communication links between neighbouring master stations (wire or wireless). If the channel for operation is chosen by the master only, the following problem may occur.

In Figure 3 two base stations (BS) start operation on the same channel. After that wireless terminals (WT) associate to the system operated by the left BS. These WTs pollute the radio cell of the other BS with strong interference (grey area in Figure 3). Consequently, this BS will not be able to operate appropriately as it is within interference range of WTs in the neighbouring cell. Even if the right BS would not be in the grey area, parts of its radio cell would be unusable. Therefore, the channel for operation must be chosen by both, master and slave.

6 Basic rules

Systems which offer services with a guaranteed Quality of Service (QoS) to the users can only be realised with reservation based access protocols, particularly, if a limited maximum delay time is required. Those systems have to be protected and separated from systems which only offer ABR/UBR (Available/Unspecified Bit Rate) services.

Due to their totally different access methods we do not believe that it is possible to share a common frequency channel between reservation based and non-reservation based systems. We propose a channelisation of the available bandwidth. Certain frequency channels should be assigned to each type of system exclusively. E.g., the lowest frequency channel shall be assigned to non-reservation based systems and the highest frequency channel shall be assigned to reservation based systems.

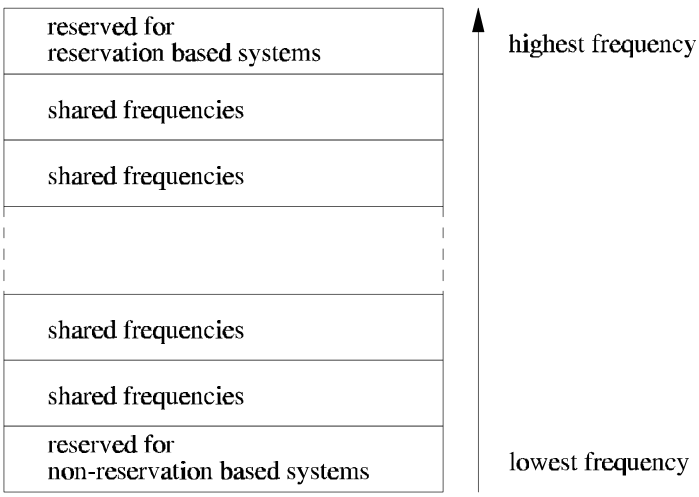

Figure 4: Frequency channelisation

The frequency channels in between are shared between the two types of system using the following rules:

Non-reservation based systems:

1. Look at the lowest frequency channel. If it is silent, start operation here, otherwise go to 2.
2. Go to next higher frequency channel. If it is silent, start operation here. Otherwise go to 2, if there are still frequency channels left, or go to 3.

3. If all frequency channels are occupied, the non-reservation based system starts sharing a frequency channel with another non-reservation based system. Thus it has to determine whether a frequency channel is occupied by a non-reservation based system or by a reservation based system. The non-reservation based system starts sharing a frequency channel occupied by other non-reservation based systems following the rules for non-reservation based systems listed below. This is always possible because at least at the lowest frequency channel a non-reservation based system is working.

Reservation based systems:

1. Look at the highest frequency channel. If it is silent, start operation here, otherwise go to 2.

2. Go to next lower frequency channel. If it is silent, start operation here. Otherwise go to 2, if there are still frequency channels left, or go to 3.

3. If all frequency channels are occupied, the reservation based system has two opportunities: withdraw from communication or share a frequency channel with another reservation based system if this is possible and allowed.

7 Frequency sharing rules for non-reservation based systems

The rules which are common in [3] and [4] are dealing with a maximum time a channel is occupied by one single station as well as a minimum time between two channel occupations of the same station. The maximum hold time shall allow the transmission of a modest amount of data, which is sufficient and typical for non-reservation based systems, e.g. 1000 µs maximum hold time. The minimum time between two channel occupations shall give other stations the chance to access the channel. This time must be long enough to ensure a sufficient probability for other stations to enter the channel and must be as short as possible to enable a high total data rate for a single station. So it may be in the range of 10 µs - 100 µs [3], [4].

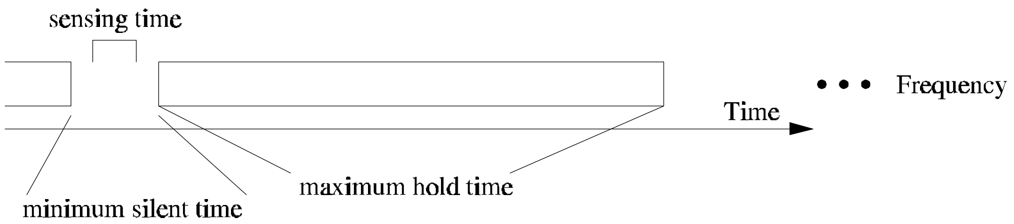

Figure 5: Sharing rules for non-reservation based systems

Applying only these two rules might be enough assuming all non-reservation based systems run an efficient CSMA/CA protocol. In this case a channel sensing before entering is just included in the systems protocol and must not be defined by the frequency etiquette. On the other hand a carrier sensing protocol defined by the sharing rules lowers the number of probable collisions as it is not guaranteed that only CSMA/CA type systems are operating as non-reservation based systems. Therefore, we propose a short channel sensing time before access, e.g. 50 µs. Systems have to find the channel free for this time. This time should be shorter than the minimum silent time, because otherwise one station is able to block the channel. Finding the channel occupied a station has to start some kind of back-off procedure with a random back-off time. The back-off time should be limited by a minimum (200 µs) and a maximum (5000µs) value.

8 Frequency sharing rules for reservation based systems

Basically there are two options for sharing rules for reservation based systems: with and without information exchange.

In order to enable information exchange between different systems a dedicated small band control channel is needed. All systems must have an additional modem and protocol stack for the control channel. This additional modem can be very simple, robust and cheap. Protocols for a dedicated control channel with a common modem are for further study.

Rules without information exchange are based upon energy detection techniques. As reservation based systems are expected to have bursty traffic characteristics it is not possible to extrapolate the future traffic from channel sensing information. Moreover reservation based systems are expected to guarantee the quality of service for time bounded services. Therefore, we propose a fairly long channel sensing time before accessing a channel for the first time, e.g. 1 second. This quite long channel sensing time is not limiting data rates, because it is only used once, when starting servicing. A system occupying this channel has to transmit something in a periodically way to keep the channel occupied. A maximum channel holding time is not specified in order to enable quality of service guarantees. When a system releases the channel after some time, there is no guarantee that it will be granted a channel again in time.

Different from other proposals we do not limit the application of these procedures to the master of a reservation based system but expand it to the slaves in order to handle hidden stations of neighbouring systems.

9 Acknowledgements

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10 References

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