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Source(s)	Mariana Goldhamer Alvarion Tel Aviv, 21 HaBarzel Street Israel Voice: +972 3 6456241 Fax: +972 3 645 6204 mailto:marianna.goldhammer@alvarion.com
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Ideas for elements of a coexistence protocol

Mariana Goldhamer
Alvarion

Introduction

This paper presents ideas for:

- Reservation concept with different sources of interference;
- Multiple access concepts for inter-system communication;
- Communication using messages;
- Higher level coordination;
- Spectrum sharing etiquette;
- Distributed systems approach;
- Inter-system PHY communication.

At the end, is presented the operational example from [1].

Reservation concept

Systems using scheduling

This idea has been already presented in [1]. A short overview follows:

Here down is shown how a IEEE 802.16 system, can take active advantage of its predictive behavior and announce its Tx/Rx reservation periods by simple PHY signaling:

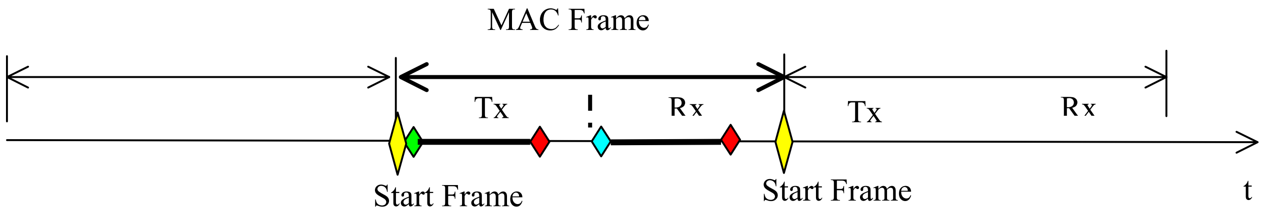

Figure 1 Basic Tx /Rx Reservation signaling

The signaling from the figure above allows to:

- Identify the system;
- Determine the periodicity of the MAC frames;
- Determine the MAC frame duration;
- Determine the Tx duration for different reservations;
- Determine the Rx duration for different reservations.

The principal candidates announcing their reservation periods are APs (Access Points) and for hidden systems situations, Subscriber Terminals (STs).
A more complex communication mode may include messages, as shown in the next figure.

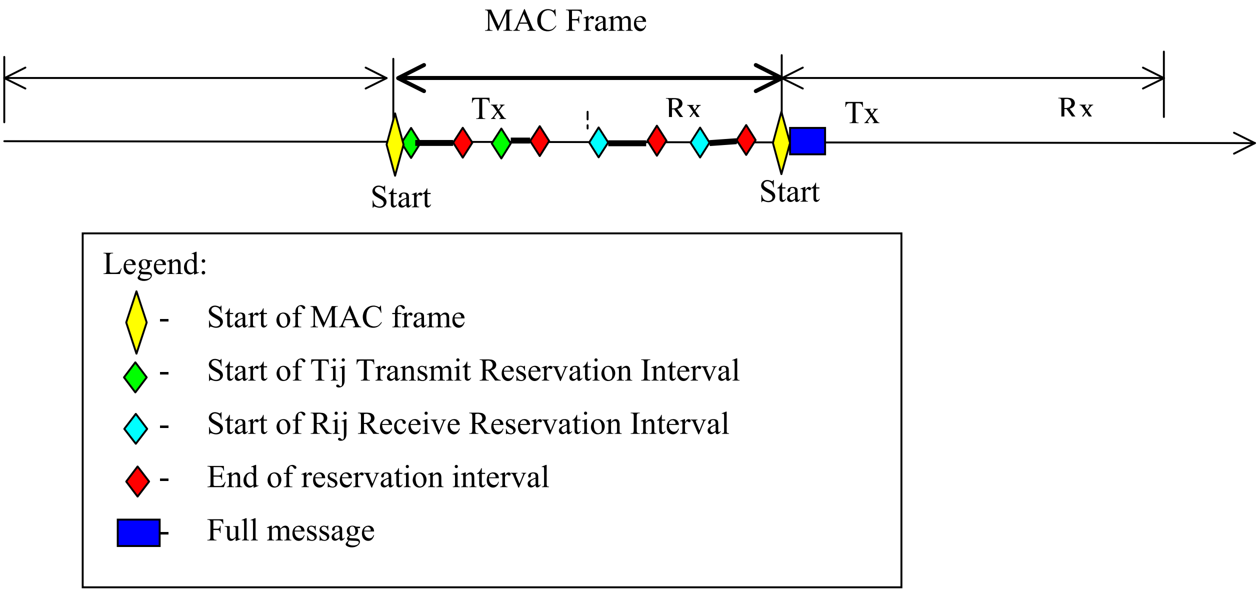

Figure 2 Transmission of Tx / Rx Reservation and other parameters

Systems using bursty access

The systems using bursty access will have mixed Tx/Rx intervals, any separation being impossible. IEEE 802.11 is an example of such a systems. These systems may announce the PHY activity intervals, as shown in Fig. 3.

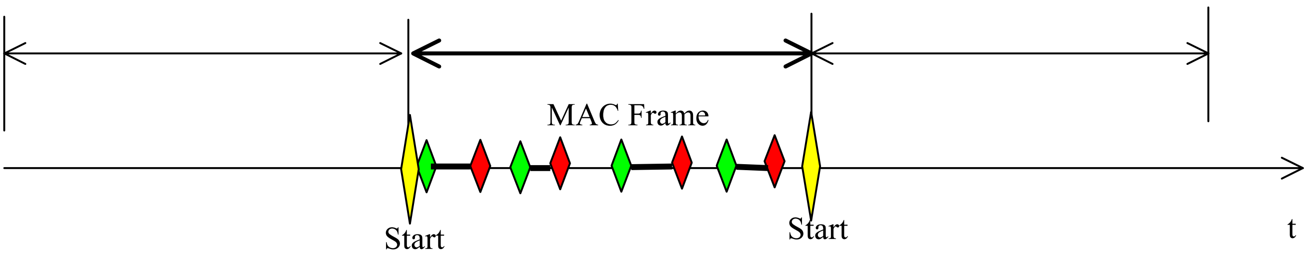

Figure 3 Reservation of activity intervals

Multiple access concepts for inter-system communication

However, exist the danger that, especially when synchronizing Tx/Rx intervals (the necessity has been demonstrated in [2]), the previous mentioned signaling, transmitted by different APs or STs will occur in the same time. In order to avoid such a situation, a multi-frame should be created.
A super-frame, having well-known repetition period and time-slot duration is proposed. The super-frame periodicity of PHY signaling may be relatively long, for example 10sec. Every system may chose free slots

(from noise + interference p.o.v.) for signaling. The time intervals for reservation signaling will be known a priori (part of the general multi-frame structure). The slots are chosen in time domain, and in every slot the signaling is done on the operating frequency of the system.
Hidden stations may use more slots, distributed in a way that will permit more frequent communication of their Tx / Rx reservations. This may be needed due to the fact that Base Station traffic is an integrated traffic, having more stable characteristics, while a station traffic may change more frequently.

Fig. 2 shows a super-frame structure, being used by different systems, on different frequency channels:
The advantage of the super-frame structure is its cognitive property: the place for signaling repetition, of a system of interest, can be previewed.
A system may use more than 1 slot, is its periodicity frame is longer than 1 slot. However, a system should be prevented for using more than a given percentage of the available slots.
The operating frequency of the system is identified, in fig.4, as channel i.

Multi-frame duration

Slot 1 Channel j System m	Slot 2 Channel i System q	…..	Slot i Channel c System n	…..	Slot N Channel k System n	Slot 1 Channel j System m	Slot 2 Channel i System q

Figure 4 Super-frame structures for reservation protocol

Communication using messages

During each system reservation period, a special time-slot may be allocated to receive requests from other systems (Request Interval). Such a period is shown in Fig. 5, where was added the reservation for interactive requests. In response, the system may send up-dated parameters.
Multiple systems may try to access the same Request Interval. A good practice will be to use it as "contention window" Request interval, the actual allocation for interactive requests messages being communicated in the full message field. Every system requesting access will be scheduled at a different time.

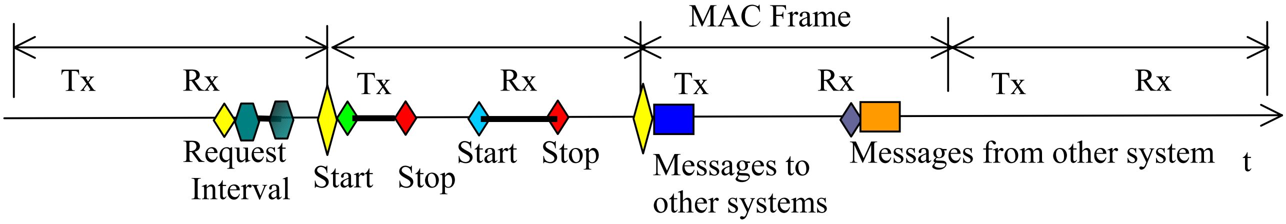

Figure 5 Interactive requests

Higher level co-ordination

There are a number of solutions for system coordination, from simple to more complex.
A relatively simple approach is that every system will behave according to a priory agreed rules, like a spectrum sharing etiquette. A more complex approach involves more complex messages and a more advanced coordination, suitable for spectrum sharing by distributed systems.

Spectrum sharing etiquette - example

A simple rule for spectrum sharing may be the following:

- if a system senses interference, will reduce its Tx/Rx periods, to allow other systems to use the spectrum in the free created intervals;
- if a system senses interference, will try to schedule its activity periods in time-intervals that are interference free.

This method may mitigate the interference, but the coordination level is low.

Distributed system approach

With this approach, the systems will send messages to announce their operating environment to every other system sharing the spectrum and will negotiate the spectrum sharing in both time and frequency domains. Principles used in IEEE 802.16-2004, for distributed Mesh, may be useful for distributed spectrum sharing.

Inter-system PHY communication

Requirements

Technology independence

The proposed modem should be considered as "technology independent". Energy transmission in pulses, as in Radar case for 5GHz, may be an example of such technology. Other possibilities are classical modulations, as QPSK, GFSK or pulse position modulation.

Data rate

Due to the fact that the reservation periods are changed at relatively long intervals, it is possible to use relatively low data rates for the "coexistence channel", as 1Mb/s. For example, considering messages of 100 bytes, at 1Mb/s communication rate, the needed transmission time will be 1ms. Considering a super-frame of 10s, this will represent only 0.01% from system capacity.

C/I

Due to the low data rate requirement, it makes sense to use only low modulation orders, like QPSK, obtaining relatively low C/I.

Multi-path resistance

Due to the fact that the communication will use low modulation states, operation with an effective delay-spread power level of –7dB should be an acceptable requirement.

Modulation and coding

The appropriate PHY will be defined following the evaluation of different proposals, in the drafting phase.

Operational example, with 802.16 and 802.11 devices

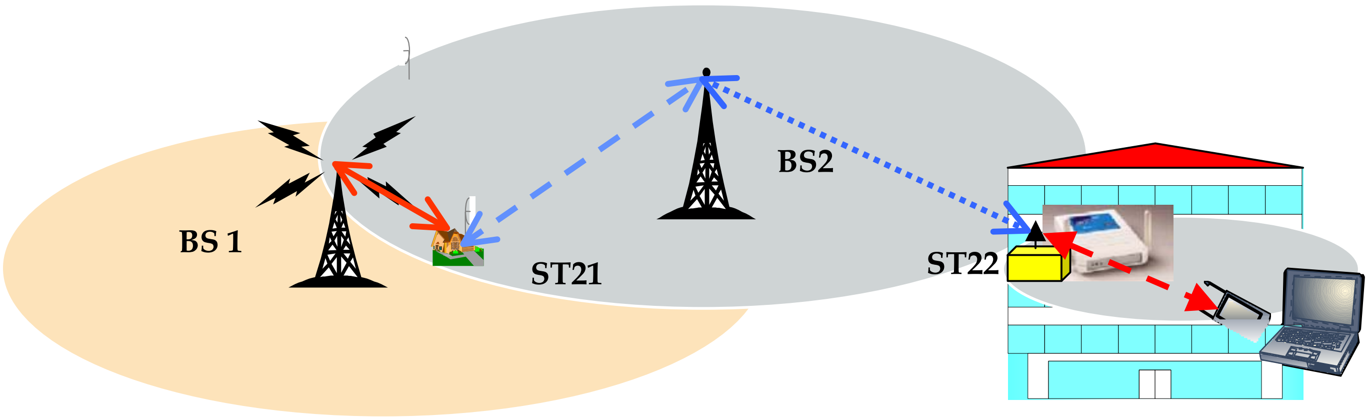

Figure 6 Deployment example

Lets suppose that BS1 (Base Station 1) is occupying frequency F1-F4 and Base Station 2 is occupying frequency F6.
BS1 has 4 APs (sectors, with synchronized MAC frames). BS2 has 1 omni AP.
System 2 is deployed after System 1.
System 1 is transmitting at regular intervals, for 2 consecutive MAC frames, information regarding:

a. AP ID and Tx reservation
b. AP ID and Rx Reservation

The information is transmitted on all the used sectors, using different slots in the multi-frame structure.
BS2 – AP - will recognize that spectrum sharing info is transmitted. BS 2 will identify the sector interfering with itself.
The spectrum sharing will take place as follows:

Sharing Etiquette approach 1:
To avoid/reduce the interference, BS2 chose to synchronize its Tx and Rx periods with BS1.
BS2 starts to work. Its station, ST21 suffers from interference from BS1, and BS2 is aware of that.
BS1 suffers from interference from ST21.
ST22 is interfered from a device, for which BS2 is probably hidden (say 802.11 AP).

Sharing Etiquette approach 2:
BS1 reduces both its Tx and Rx durations.

Sharing Etiquette approach 3:
BS2 schedules the communication with ST21 in the period of time, when BS1 is not working. Interference is avoided.

Sharing Etiquette approach 4:
When told by AP2, ST22 will announce its intended Tx and Rx transmissions (reservation approach).

Sharing Etiquette approach 5:
The 802.11 AP will enter the PCF function. In this mode, will block communication inside its cell, during ST22 reservation intervals.

Sharing Etiquette approach 6:
802.11 AP might search for another operating frequency, with a higher frequency gap

Sharing Etiquette approach 7:

A 802.11 STA is the one hearing the ST22 messages. The 802.11 STA will relay the reservation information to its 802.11 AP (if in P-MP mode) or to the other connected stations (if in Ad-hoc mode)

Sharing Etiquette approach 8:

The stations not hearing the ST22 reservation signals, will refrain to communicate with the stations hearing the signals, during the reserved Tx and Rx intervals.

The general resulting time-frequency behavior is illustrated below.

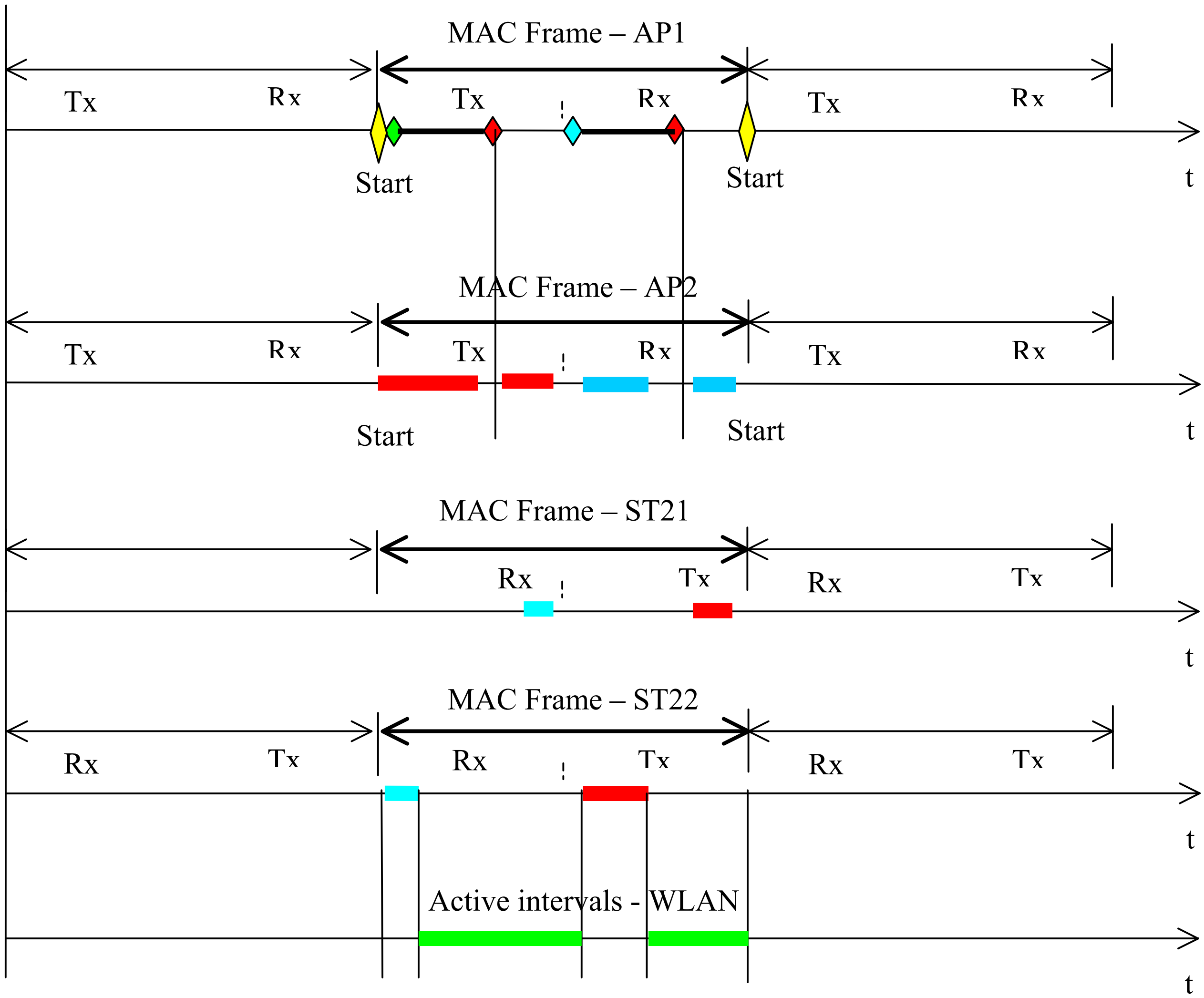

Figure 7 Communications intervals when applying sharing protocol

Conclusion

802.16 air protocol has excellent sharing properties, due to its predictable / cognitive behavior. The predictable behavior should be enhanced with suitable signaling and messages, in order to optimal use a cognitive spectrum sharing.

approach. This approach may probably resolve not only co-existence between 802.16 like systems, but also co-existence of 802.16 like systems with bursty systems, like 802.11.

A spectrum sharing protocol is feasible; the details of its different components will be defined through the standardization process.

References

[1] Mariana Goldhamer, "Idea for spectrum sharing in LE bands", in IEEE C802.16-04/17, July 8, 2004.
[2] Mariana Goldhamer, "Interference scenarios in 2.4GHz and 5.8GHz UNII band ", in IEEE C802.16-04/14, June 28, 2004.