Nordic VLSI ASA

RF communication in a multi-user environment

1. GENERAL

Since more and more systems are using RF communication, and most of them are operating in an ISM (Industrial, Scientific, Medical) band the need for a way to harmonize the coexistence of systems using the same frequency resources, are urgent. In this white paper we will discuss different techniques for dealing with the problems caused by RF traffic from other systems than our own.

2. TECHNIQUES FOR HANDLING DISTURBING TRAFFIC

There are different ways on how a system based on a combination of TDMA (Time Division Multiple Access) and FDMA (Frequency Division Multiple Access) uses the time and frequency domain. Most of the systems have a “bursty” use of the time domain, meaning that they transmit in short bursts and keep quiet in between each burst. For the use of the frequency domain there are in major three different ways a system can operate:

- Fixed single channel (Low complexity)
- Dynamic channel assigning (Medium complexity)
- Frequency hopping (High complexity)

A fixed single channel system is typically a system where the units do not have the possibility to negotiate which channel they shall use or distribute a common system clock. Normally this will be a system with a transmitter in one end and a receiver in the other. Such a system will be able to use different channels, but the channel for operation will be selected once at start-up. An example of such a system is a wireless mouse.

Dynamic channel assignment is a method where all units involved must have a transceiver. This enables the possibility for the receiving unit to acknowledge all received packets, which will make the transmitting unit able to detect packet loss and initiate a re-transmission of the lost packet. It will also make the system able to calculate the packet loss ratio (PLR.) And the system can be made so that the units change traffic channel if the PLR reaches a given threshold. The channel change plan can be implemented as a table or as a “go N up/down” algorithm. The most important part of a channel change is that both units actually change channel. Since it is the transmitting unit that will be able to detect the PLR it will also be the part responsible of initiating the channel change. This is done by sending a “change channel to X” (X represent the new channel) packet to the receiver. The receiver will acknowledge and change to the predefined channel. The receiver will wait on that channel for a few milliseconds for the transmitter to arrive. If the receiver does not receive anything from the transmitter it will go back to the previous channel assuming that the transmitter did not get the acknowledgement. The receiving unit will stay on this channel until it hears from the transmitter again.

The transmitter will wait until it receives the acknowledgement for the "change channel to X" packet. If it does not receive the acknowledgement it will re-send the "change channel to X" packet until it reaches an acknowledgement or times out. When the acknowledgement is received, it will change channel and send a "report-in" packet to the receiver on the new channel. If the receiver does not answer in a certain number of tries, this channel is probably busy also so it has to go back to the previous channel and negotiate with the receiver again. If the receiver answers the "report-in" packet, communication will go as normal on the new channel. A flow chart of this operation is shown in Figure 1.

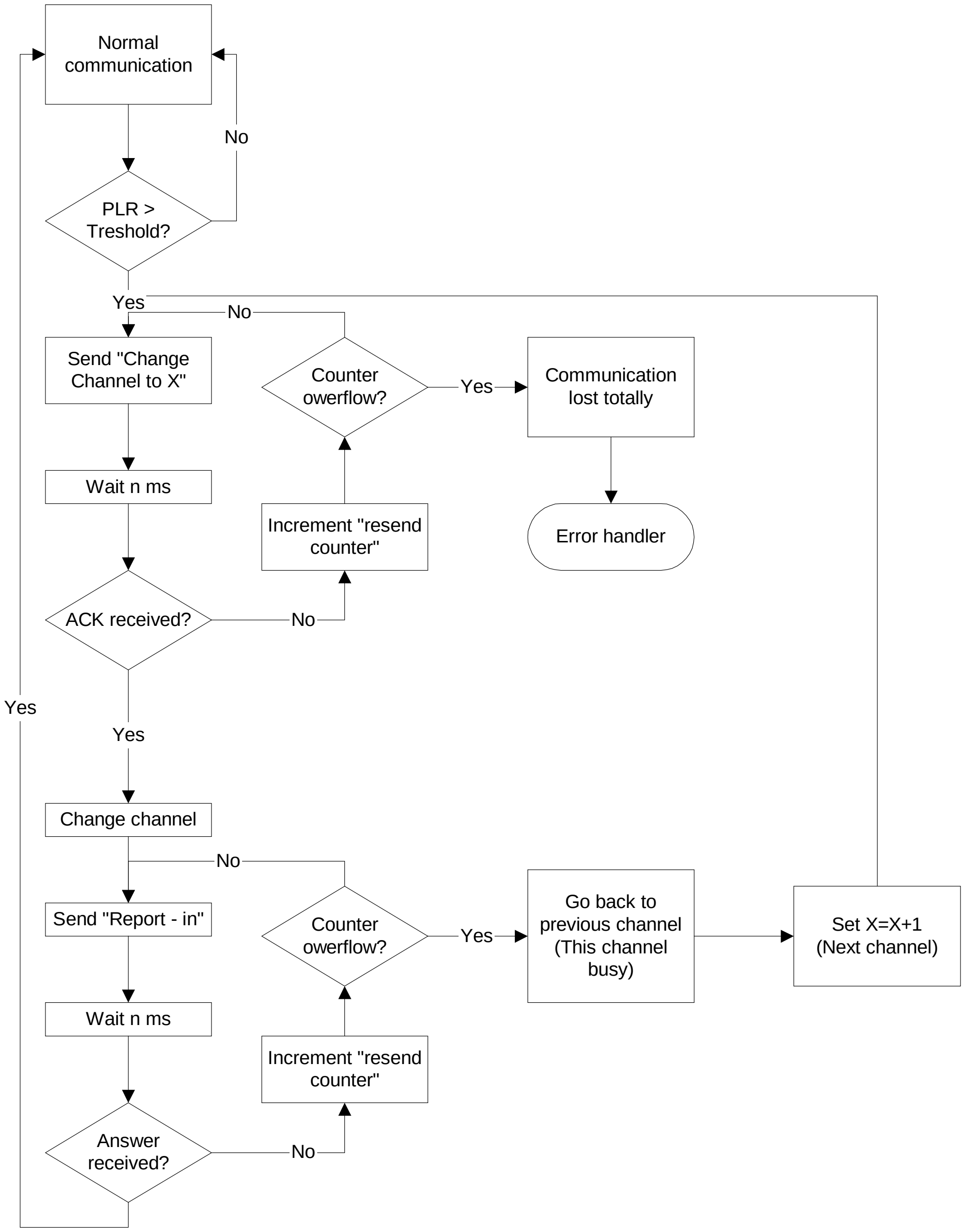

Figure 1 Flow chart for the dynamic channel change protocol for the transmitter

Frequency hopping is a very safe way to avoid communication failure due to total jamming of a traffic channel. The units in a frequency hopping system change channels after a predefined channel table and in a time synchronous manner. Generating a global clock based on each units distributed clock gives a reference for the time synchronization. This requires massive “system control” traffic on air. A slower frequency hopping can be made without a global clock as a reference. This will look much the same as dynamic channel assignment, but instead of waiting for a PLR higher than a threshold, a channel change will be initiated each time a packet is transmitted. A frequency hopping protocol must also run a flow control like acknowledgement to ensure that all the information gets trough. Frequency hopping is most used by systems operating with so high output power that the frequency regulation demands the use of it.

3. DYNAMIC CHANNEL ASSIGNMENT EXAMPLE

To highlight the functionality of the dynamic channel assignment method an example of a system using it will be described.
A gaming control system has the possibility of handling N game controllers at the same time. Each game controller are interfaced with the control system trough a wireless 2.4GHz link, meaning that each game controller has its own receiver.
To begin with our system has three game controllers operating at three different channels as shown in Figure 2.

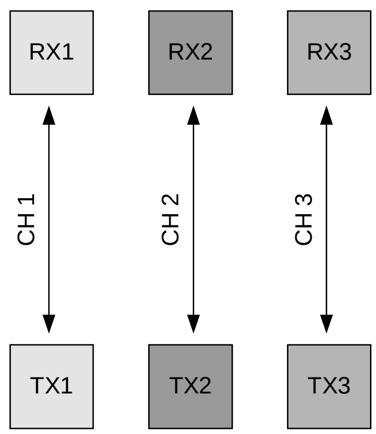

Figure 2 Three game controllers operating at different channels

After a time of operation a fourth competitor wants to join the game. He will then connect his game controller to a available port in the game control system and switch on his equipment. The last time he used it, his game controller where using CH2. By default the game controller want to use the same channel as before. Then we have the situation as shown in Figure 3.

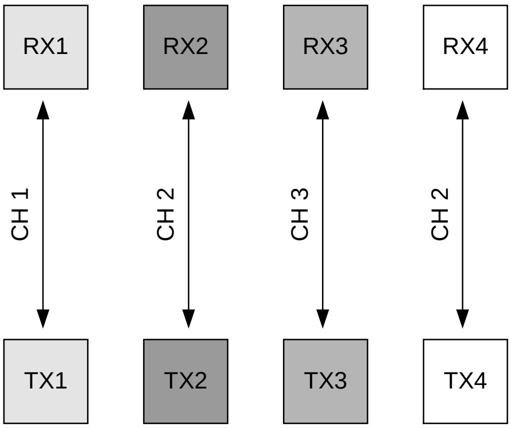

Figure 3 An intruding party uses CH2

When the TX4/RX4 pair starts to communicate, the TX2/RX2 pair will register an increase in the PLR. The TX4/RX4 pair should also register a high PLR. The pair that first gets a PLR higher than the threshold will start to change the channel. It should be implemented so that when a pair start up on a channel, the threshold should be low and get increasingly higher the longer it stays on the channel. This will cause the intruder pair to change channel first. Finally after the dynamic channel assignment protocol has been working, the result will be as shown in Figure 4.

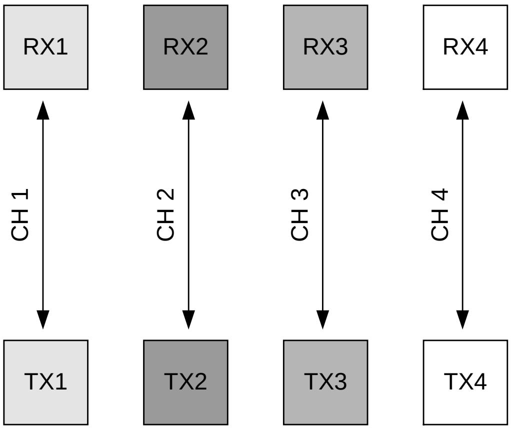

Figure 4 The result after dynamic channel assignment

4. CONCLUSION

For the three methods described in this white paper, the dynamic channel assignment method is the one that gives most protection vs. implementation complexity. It will cover the need for most of the applications using multi channels in the ISM bands. Fixed single channel will work fine for applications like a wireless mouse because every data packet is not crucial for the functionality. Frequency hopping will be very complex to implement and be overkill for those applications that can operate on a single channel until a disturbing source arrives.

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