Techpaper – Coexistence of Wi-Fi and Wireless ePaper / electronic shelf labels

This document describes the technical background and the mechanisms implemented in the LANCOM E-series access points for the interference-free parallel operation of LANCOM access points and SES-imagotag Wireless ePaper Displays / electronic shelf labels.

The integration of a Wireless ePaper system into a Wi-Fi access point offers the advantages of reduced investment costs and less effort of installation. The reduced number of network components simplifies the administration of the overall network.

Typical applications for Wireless ePaper systems include electronic room-signage systems or electronic shelf labels (ESL) in large shopping centers. In the following, we use the terms Wireless ePaper and ESL synonymously.

Basics

Because Wi-Fi based on IEEE 802.11b/g/n and Wireless ePaper systems use the same frequencies in the 2.4-GHz ISM band, LANCOM E-series access points support a range of functionalities that enable the two wireless technologies to coexist in the 2.4-GHz frequency band. These features are described in this document.

Wi-Fi

IEEE 802.11b/g/n transmits data in the 2.4 – 2.4835-GHz frequency range. The frequency range is divided into 14 channels. The number of available channels depends on the country where the network is operated. For example, in Europe 13 channels are freely available for use. To enable multiple access points to operate optimally, the various access points need to transmit on different, non-overlapping channels. If, for example, three access points need to operate in parallel in the 2.4-GHz frequency band, the recommended channels to use are 1, 6 and 11. Overlaps are avoided here as the channel bandwidth is 20 MHz. In the 2.4-GHz frequency band, the IEEE 802.11b/g/n standard prescribes a maximum transmission power of 100 mW. Figure 1 illustrates this situation.

2.4-GHz Wireless ePaper / electronic shelf labels

The Wireless ePaper system operates on one of 11 predefined channels that are also in the 2.4–2.480-GHz frequency range. Unlike the case for Wi-Fi, overlapping channels do not present a problem here. The individual channels are illustrated in Figure 1. The channel-management functionality integrated into the LANCOM E-series access points ensures that the channels are automatically allocated to avoid any overlapping of the Wireless ePaper channel with a Wi-Fi channel. If, for

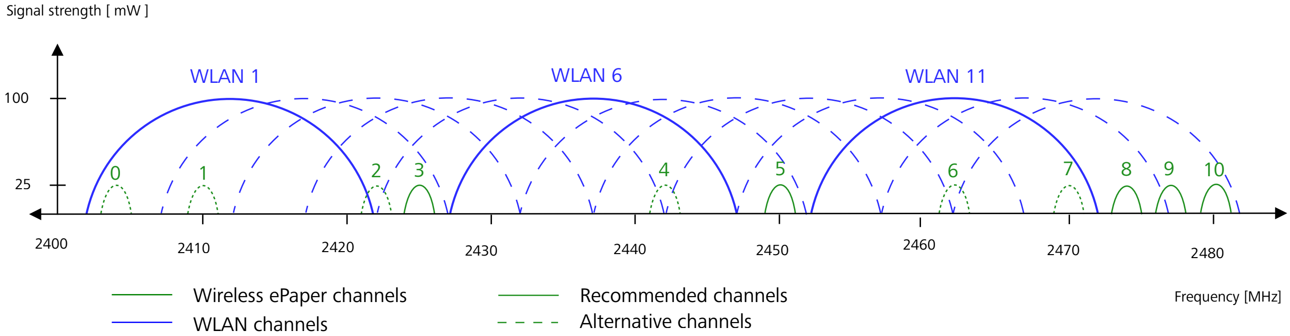

Figure 1: Coexistence of Wi-Fi and Wireless ePaper in the 2.4-GHz frequency band

example, the Wi-Fi operates on channels 1, 6, and 11, the Wireless ePaper channels 3, 5, 8, 9, 10 are in unoccupied frequencies. These Wireless ePaper channels also allow the access point to connect more quickly to the Wireless ePaper Displays.

The maximum transmitting power of the Wireless ePaper module is 25 mW. This is significantly lower than the power used in for Wi-Fi (100 mW). The Wireless ePaper system transfers data by means of the TDMA (time division multiple access) method. Each Wireless ePaper Display is programmed with a fixed time slot. The main advantage of the TDMA method is that both the access point and the Wireless ePaper Display know the exact time at which communications start and end. The Wireless ePaper Display uses this information to disable its receiver outside of its own time slot, which reduces its energy consumption.

For the duration of a time window, the access point transmits the data to the Wireless ePaper Displays. At the end of its own time slot, each Wireless ePaper Display confirms the receipt of the data by sending a confirmation message. If this confirmation message is lost, the access point assumes that communication has failed, and sends the same data again. The transmitter only deletes the data from its transmit buffer once it has received a confirmation message. This ensures that no messages get lost. To ensure that the confirmation message arrives at the Wireless ePaper module in the access point, the transmitter in the Wi-Fi module is switched off for this brief period of time by a special procedure (patent pending). This procedure ensures that no data is lost on the Wi-Fi interface. Having the transmitter in the Wi-Fi module disabled for this brief period has a minimal impact on the Wi-Fi throughput rate, and in practice the effects are unnoticeable. The end result is that reliable communication between the access point and Wireless ePaper Display is guaranteed at all times.

Interference-free parallel operation of Wi-Fi and Wireless ePaper modules

The multi-stage approach described in the following ensures that the Wi-Fi and Wireless-ePaper modules operate optimally and in parallel even in complex network topologies:

- Automatic Wi-Fi and Wireless ePaper channel selection by the LANCOM E-series access point (frequency-range optimization)
- Access-point controlled separation of the Wireless ePaper communications from the Wi-Fi communications (time-slot separation)

Optimal selection of the Wi-Fi channel

The LANCOM feature "Active Radio Control" (ARC) optimizes Wi-Fi channel distribution even in complex network scenarios. Details about this feature are outlined in the "Active Radio Control" techpaper, which is available from the LANCOM website.

Optimal selection of the Wireless ePaper channel

The LCOS operating system in the LANCOM E-series access points uses the following multi-stage approach to ensure that the channels are optimally distributed for the Wireless ePaper modules:

The first step is for the network to specify an access point, which is responsible for the allocation of the Wireless ePaper channels. In the following, this central instance is referred to as the master access point. All of the non-master access points are known as slave access points. The employed algorithm guarantees that the master role is always allocated to just one access point. Also, if the original master should fail, the algorithm ensures that a new master is chosen automatically.

In a second step, the slave access points each compile a list with ratings for the Wireless ePaper channels. The preferred channels (3, 5, 8, 9, 10) receive a better rating than the other channels (0, 1, 2, 4, 5, 6, 7). The remaining Wireless ePaper channels are then evaluated relative to the Wi-Fi channels that are in operation. This means that the Wireless ePaper channels that are closer to the Wi-Fi channels are rated lower than Wireless ePaper channels that are further away from the Wi-Fi channels that are in operation.

The lists with the ratings of the Wireless ePaper channels are then sent to the master access point. The master access point also creates its own channel list based on the same criteria. This collection of lists is processed by an algorithm in the master access point, which calculates an optimized allocation of the Wireless ePaper channels.

The final step is for the master access point to allocate the calculated Wireless ePaper channels to the slave access points and to allocate the Wireless ePaper channel that it calculated for itself.

This ensures that neighboring access points do not use the same Wireless ePaper channel. It also guarantees that the Wi-Fi channel and the Wireless ePaper channel are separated by the greatest possible frequency difference.

This approach guarantees an optimal distribution of Wireless ePaper channels for up to eleven access points. To optimize even more complex network scenarios, the automatic approach described here should be used in addition to a manual allocation of the Wireless ePaper channels that also accounts for the spatial distribution of the access points and/or other possible sources of interference.

Quantifying the described approaches

The following experiment illustrates the approaches as described:

- An access point sends an update to 294 Wireless ePaper displays (type G1 2.7 BW).
- The Wi-Fi interface is placed under full load by an iPerf test sequence. The transport layer protocol is TCP. The iPerf server runs on a laptop with the iPerf client running on another laptop. In this case the iPerf client is connected to the LAN interface of the access point. The iPerf server is connected via the Wi-Fi interface. (iPerf-Client -> LAN -> Access Point -> Wi-Fi -> iPerf-Server).
- The surrounding environment contains 50 third-party Wi-Fis, which place additional load on our network.
- The distance between the access point and the Wireless ePaper Displays is 4 m.

The following data were collected:

- Transfer time for the Wireless ePaper Display update
- Error rate on the Wireless ePaper Displays
- Throughput on the Wi-Fi interface

Five measurements were performed. The measured values were averaged. The retry-rate was deliberately set to 0 to provoke transmission errors. 5 retries are specified by default. The following table shows the different scenarios that were tested and summarizes the most important information:

	Transfer [sec]	Error rate [%] for 0 retries	Error rate [%] for 5 retries	Wi-Fi through-put [Mbps]
Scenario 1: Display update without Wi-Fi data traffic	567	< 1	0	-
Scenario 2: Protected Display update without Wi-Fi data traffic	569	< 1	0	-
Scenario 3: Display update with Wi-Fi data traffic	1489	77	< 3	56
Scenario 4: Protected Display update with Wi-Fi data traffic	718	14	0	40

Evaluation of scenarios 1 and 2

In these two scenarios, activating the protection mechanism for Wireless ePaper communications had no effect on the transfer time or error rate.

Evaluation of scenarios 3 and 4

By activating the protection mechanism for the Wireless ePaper communication, the error rate improved in this case (full Wi-Fi load) by a factor of 5.5. At the same time the transfer time was halved, so the Wi-Fi interface was able to start transmitting at full speed significantly earlier.

The relatively low Wi-Fi data rates are due to the frequency band in the test case being subjected to the additional load of 50 third-party networks. At this point we should clarify that the iPerf measurement is a synthetic test to place an almost full load on the interface in order to provoke a higher error rate. In real world scenarios, network loads like this are rare. We can thus assume that a real-world loss of data throughput would be significantly lower. The Wi-Fi user experience is not negatively affected by such minimal losses in data throughput. These results coincide with the practical experience that we have gained so far, where there was no perceptible impairment of the Wi-Fi transmissions.

Summary

The parallel operation of Wi-Fi and Wireless ePaper is significantly enhanced by the automatic protection mechanisms in the LANCOM E-series access points, which provide automatic channel selection and a separation in terms of time and frequency. These mechanisms demonstrably improve the error rate and significantly reduce the transfer times of updates to Wireless ePaper Displays. The shortened transmission time serves to extend the battery life of the Wireless ePaper Displays.

In complex installations with many thousands of Wireless ePaper Displays, the use of the protective mechanism leads to a significant reduction in operating costs. In contrast, an installation of Wi-Fi access points and separate Wireless ePaper access points not only means twice the hardware costs and twice the costs for cabling and coverage, it also completely lacks the protective mechanisms that allow the Wi-Fi and Wireless ePaper to operate in parallel.

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