8 Measurements of Service Discovery in Wireless Sensor Networks

8.1 Measurement Setup

The setup for the measurement of service discovery on a real Wireless Sensor Network is as follows. The sensor nodes in use are XBow/MEMSIC TelosB [PSC05] as shown in figure 8.1.

Figure 8.1: Wireless Sensor Node TelosB

A network of 9 nodes arranged in a grid layout at an office room ceiling has been set up, depicted in figure 8.2. The inter-node distance is 120 cm and the nodes are 40 cm beneath the ceiling. The nodes are powered by the USB connection, which is also used for measurement control and logging.

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Figure 8.2: Ceiling Network

8.1.1 Link Assessment Measurements

To vary the connectivity between the nodes, the transmission power level of the nodes is adapted. The setting of the radio chip CC2420 governing the transmission output power is called PA_LEVEL, cf. table 9 of the CC2420 datasheet [Tex07]. In [PP08] the values of the datasheet have been interpolated using a cubic spline interpolation, the resulting dBm values are listed in table 8.1.

As the distance in the testbed is low, low values for the PA_LEVEL have been chosen as well. The resulting PRR topologies have been measured for PA_LEVEL=0 to 3 out of the possible range 0 to 31. For the link measurements the nodes have been programmed with a dedicated application, that listens for received packets and forwards those packets over the USB interface. Additionally, the program can be triggered over the USB interface to transmit a specified number of packets. In turn, each node of the testbed has been triggered to transmit 100 packets with an inter-packet interval of 100 ms. Only one node has been transmitting at a time in order to avoid collisions. After a node has transmitted the 100 packets, the next node is instructed to transmit. This repeats until all nodes have been acting as the transmitter. All nodes not acting as transmitter, are acting as receiver and report the received packets over the USB interface.

Scripts automating the installation, the setup on the host computer, the test execution and the post-processing have been developed. The results of the testbed link evaluation will be presented in the following.

PA_LEVEL	Power (dBm)
31	0
30	-0.0914
29	-0.3008
28	-0.6099
27	-1.0000
26	-1.4526
25	-1.9492
24	-2.4711
23	-3.0000
22	-3.5201
21	-4.0275
20	-4.5212
19	-5.0000
18	-5.4670
17	-5.9408
16	-6.4442
15	-7.0000
14	-7.6277
13	-8.3343
12	-9.1238
11	-10.0000
10	-10.9750
9	-12.0970
8	-13.4200
7	-15.0000
6	-16.8930
5	-19.1530
4	-21.8370
3	-25.0000
2	-28.6970
1	-32.9840
0	-37.9170

Table 8.1: Power Levels of the CC2420 Radio Chip [Source: [PP08]]

With a PA_LEVEL=0 as shown in figure 8.3 no full connectivity is possible. Even some links between neighbouring nodes have a low PRR or no connectivity at all. Differences in the PRR of the links can be attributed to manufacturing differences of the radio chip (the datasheet allows variations from 0 to -3dBm for PA_LEVEL=31), differences of the hardware platform (e.g. antenna matching), slightly different alignment of the nodes, different distances to the walls as well as local differences in the noise floor.

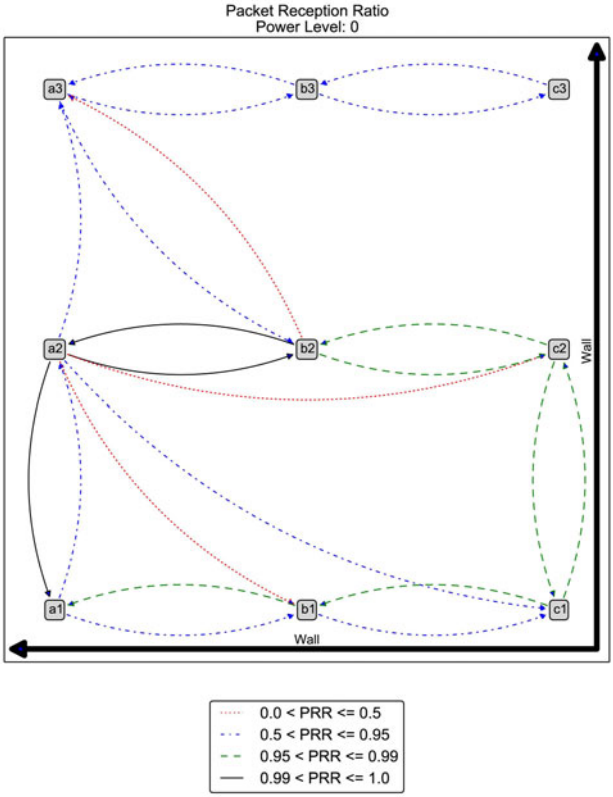

Figure 8.3: Measured Link-layer Packet Reception Ratios at Transmission Power Setting 0

With a PA_LEVEL=1, the weaker links of the previous setting have been improved to PRRs above 0.95 and additional low PRR links appear, cf. figure 8.4.

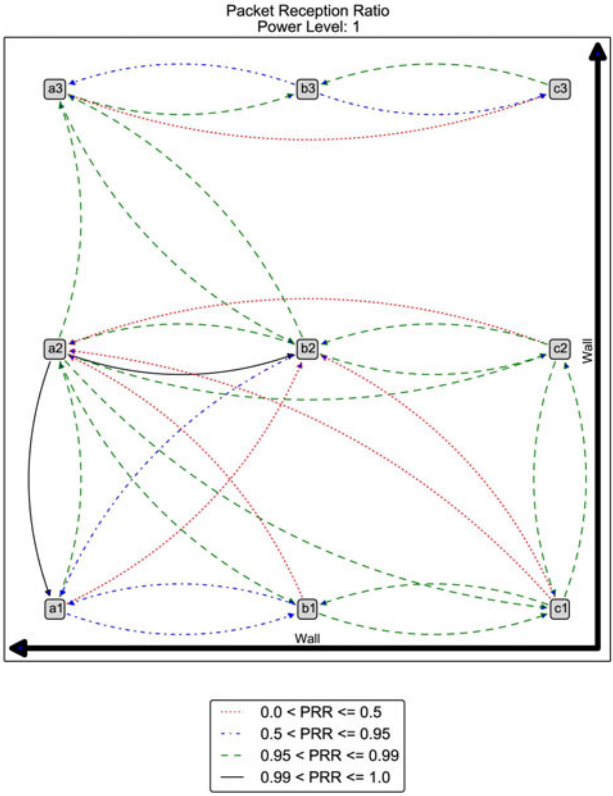

Figure 8.4: Measured Link-layer Packet Reception Ratios at Transmission Power Setting 1

With a PA_LEVEL=2, all direct neighbour links are present (with low PRR for some some links though). There are some links between nodes that have the largest distance in the testbed (i.e. nodes a1 and c3), cmp. 8.5. It can be seen that links between direct neighbors (e.g. c2/c3) can even be worse than links that are over longer distances (e.g. c1/c3). This again can be attributed to local interference and noise levels, variations in the hardware, antenna alignment differences, etc.

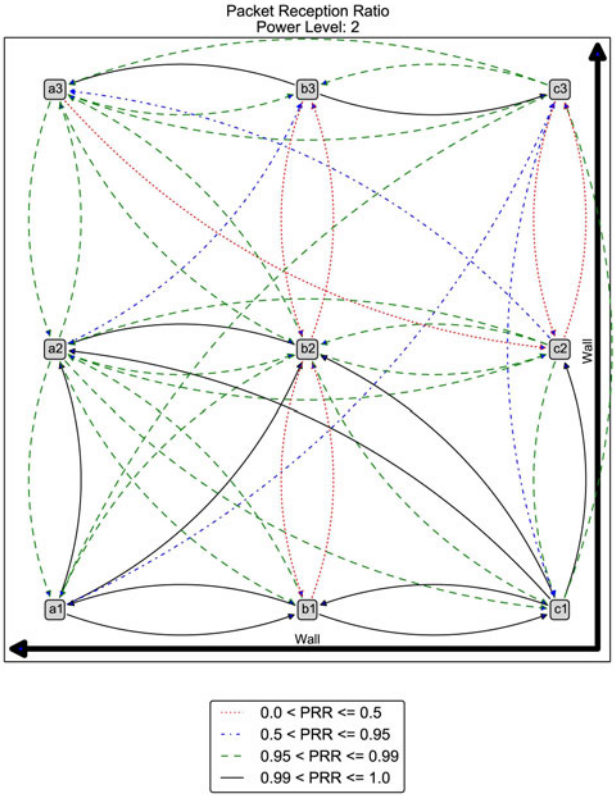

Figure 8.5: Measured link-layer Packet Reception Ratios at Transmission Power Setting 2

Having set the PA_LEVEL to 3 gives the PRRs as shown in figure 8.6. It can be seen that almost all links between all nodes have reached good PRR values above 0.95.

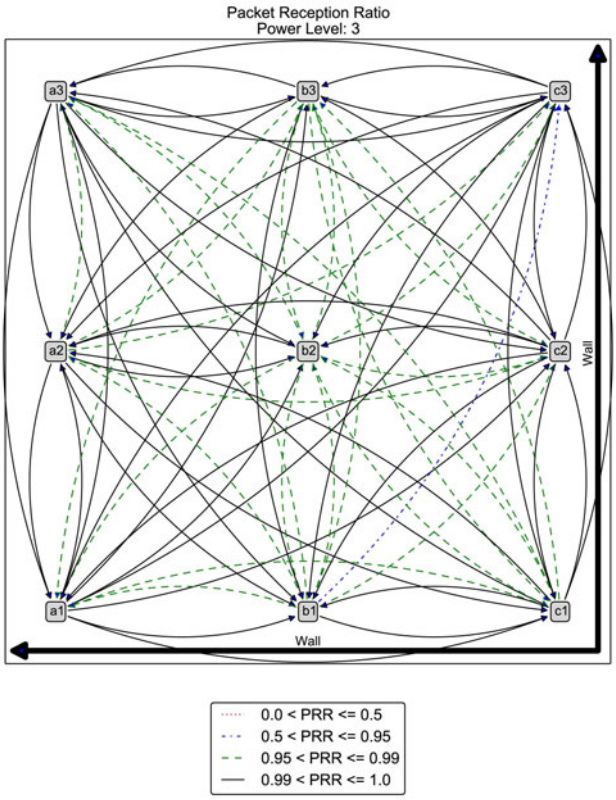

Figure 8.6: Measured link-layer Packet Reception Ratios at Transmission Power Setting 3

When comparing the measurement results with the simulation, the exact same link behaviour in a grid scenario cannot be reached due to the above mentioned reasons (manufacturing differences of the radio chip, differences of the hardware platform, slightly different alignment of the nodes, different distances to the walls as well as local differences in the noise floor). Nevertheless, a rough categorisation of the different PA_LEVELs to distances in the simulation scenarios at a PA_LEVEL=0 can be made.

For example, the PA_LEVEL=3 with its almost full connectivity can be compared to a distance of 10m (compare the simulated topologies shown in figure E.1). PA_LEVEL=2 corresponds to a distance range of about 50m (as in figure E.2), while PA_LEVEL=1 corresponds to a distance range of about 110m (compare figure E.3). Finally, PA_LEVEL=0 corresponds to a distance of about 145m (as depicted in figure E.4). Since, these are only approximate equivalences, further simulations have been performed, which use the measured link properties. Note that in most real applications the nodes would be working with PA_LEVEL=31; the reduced PA_LEVELs have been used here to mimic low density topologies in a space limited testbed.

8.2 Measurement Results

The same Service Discovery (SD) implementation which has been used to gain the simulation results presented in section 6.2 is also used for measurements. It has been slightly altered to output the debug information and enable the control of the experiment over the USB interface. The measurements have been performed in the testbed with varied PA_LEVELs as described above. Several Monte-Carlo runs have been performed for each parameter setting.

The time of the injection of a service and the time of the discovery of a new service is logged and can be used to calculate the consistency delay as it has been done for the simulation as well. Additionally, all sent packets by each node are logged and can be used to calculate the total number of sent packets.

The measurement results will be shown in comparison to the simulation results in section 9.2.