Packetloss and correlation for UDP wireless multicast

Purpose

The purpose of this test is to:

1. Measure drop rates on receivers at different locations relative to the sender
2. Figure out if there is a correlation in packet losses, i.e. if one packet is lost at one receiver, is it also lost at other receivers?

Method

Test parameters

To fulfill the purpose, we set up a test grid consisting of 16 raspberries as seen in Figure 1. We conduct several tests, varying one parameter at a time.

Parameters:

- The length between Raspberry's (b)
- The hover height of the sender (h)
- Position of the drone in the grid (x,y)

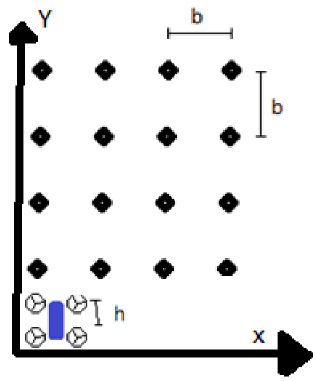


Figure 1 test grid. b: length between raspberries. h: the hover height of the drone relative to the ground

Dynamic parameters

We vary the hover height (h) and the placement (x,y) of the sender, to investigate if this has any impact on the packet loss.

Static parameters

The length between the Raspberry's have been chosen to 2 meters (b=2m). We will be sending full layer 2 packets – the layer 2 MTU is 1500 bytes. Meaning 1500 – 20(IP) – 8(UDP) = 1472 bytes of payload. This payload will consist of a 4-byte sequence number, which will be unique for every packet, and 1468 bytes of data.

Measurements

At each receiver, we store the sequence number of the captured packets. Furthermore, we note how long time there is between receptions of each packet and associate this time with the sequence number. The time is noted in a C program, operating in the user space.

At the sender, we note how many packets have been transmitted, i.e. the sequence number of the last packet sent. The time is noted in a C program, operating in the user space.

This will enable us to determine the amount of lost packets at each receiver as well as see if there is a correlation between the lost packets. The timing of the packets will give us a way of estimating the maximum and average bitrates achievable at the receivers.

In summary, we capture two things at the receivers:

- Sequence number of received packets
- The time between when the previous and current packet was received

This, together with our knowledge of a receivers position relative to the sender, will allow us to map the packetloss relative to the sender. In addition, we will investigate the correlation between packetlosses. We will plot for each packet how many receivers lost the packet. Additionally we have made an animation tool, which allows us to visualize packetloss. Furthermore, we will calculate the meantime between failure, and the correlation between two receivers.

Metadata: During the tests, we will be measuring the CPU usage of the sending (and the receiving) programs. This will give us some insight into whether bottlenecks are caused by a slow cpu, slow I/O, an occupied bus or equivalent.

Additionally, we will record any and all usage of the WiFi-channels used by the sender/receiver. Other traffic could be beacons from nearby WiFi AP or devices. This can be used to explain some of the behavior of the sender/receiver. e.g. packetloss or higher than expected delay between packets.

Scenarios

We conduct a series of test, varying one parameter at a time. We will use the following values:

- X,Y of sender: middle of the grid, corner of the grid and a grid length(8m) away from the corner.
- h: 2, 4, 6, 8 meters

Equipment

	Equipment
1.	16 x Raspberry Pi 1 model B incl. power supply and SD-card
2.	1 x Raspberry Pi 3 model b
3.	1 x RT5370
4.	16 x TP-link TL-WN722N USB Wi-Fi module

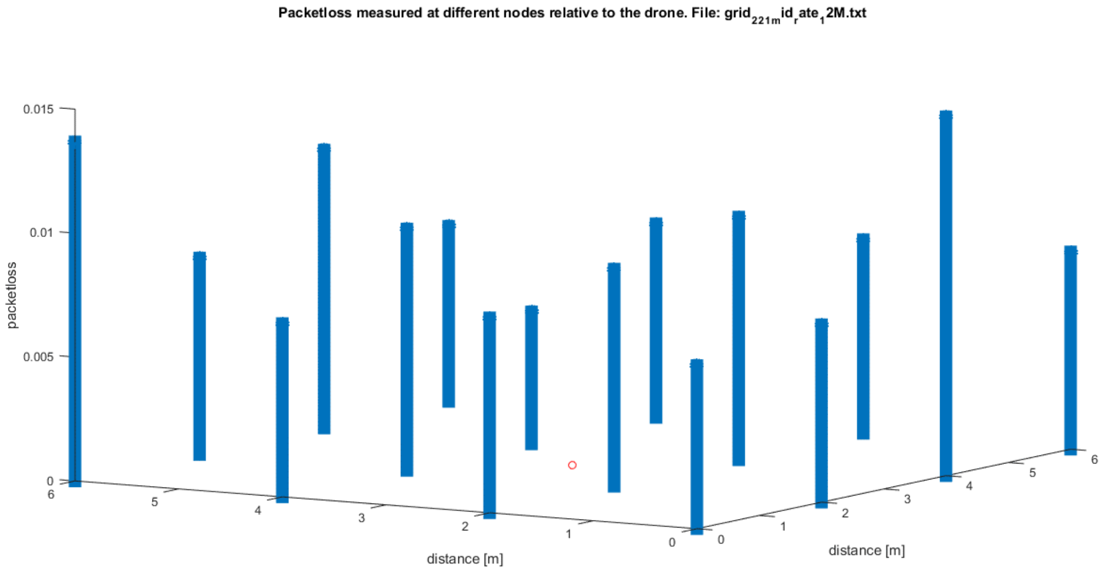
The sender consists of number 2 and 3 in the table.

One point in the grid consist of one element in number 1 and 4 from the table.

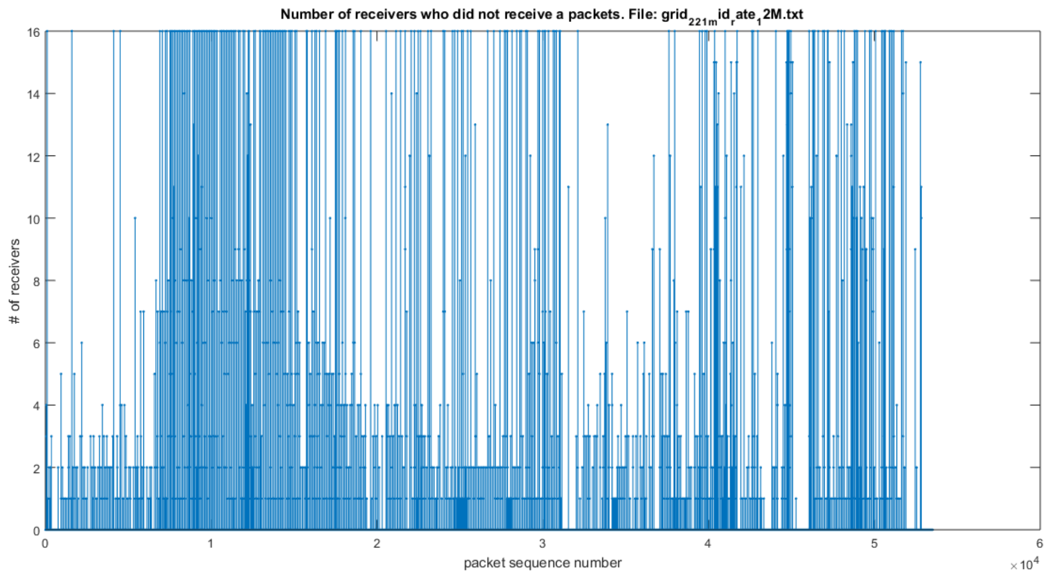
Results

During none of the tests did we run into cpu bottlenecks at any of the devices.

Now we present some results. We have several test cases, and will only present the results from one case here, due to the excessive amount of space it would require to display every case. We have chosen the case of placement = mid, h = 1 and rate = 12Mbit. First figure shows the packetloss (ratio [0;1]) averaged over one minut. The drone is placed in the middle, as indicated by the red dot



Next figure shows the number of times a packet has been dropped. Although there seems to be a high packetloss this is not really the case. The density of the stems in the plot is very high, and most packets actually have been received. Still it gives an insight to how correlated the packetloss is.



The following table shows the mean time between failure and the packetloss of each individual receiver. The MTBF is given in units of packets

Receiver	Mean Time Between Failure [packets] (larger is better)	Total # of packets lost [packets]
1	91.875	575
2	220.68	239
3	166.13	318
4	46.833	1128
5	224.43	235
6	216.42	240
7	326.67	159
8	183.43	288
9	202.98	255
10	277.95	190
11	288.21	183
12	195.05	270
13	202.98	255
14	190.4	277
15	121.17	436
16	373.54	140

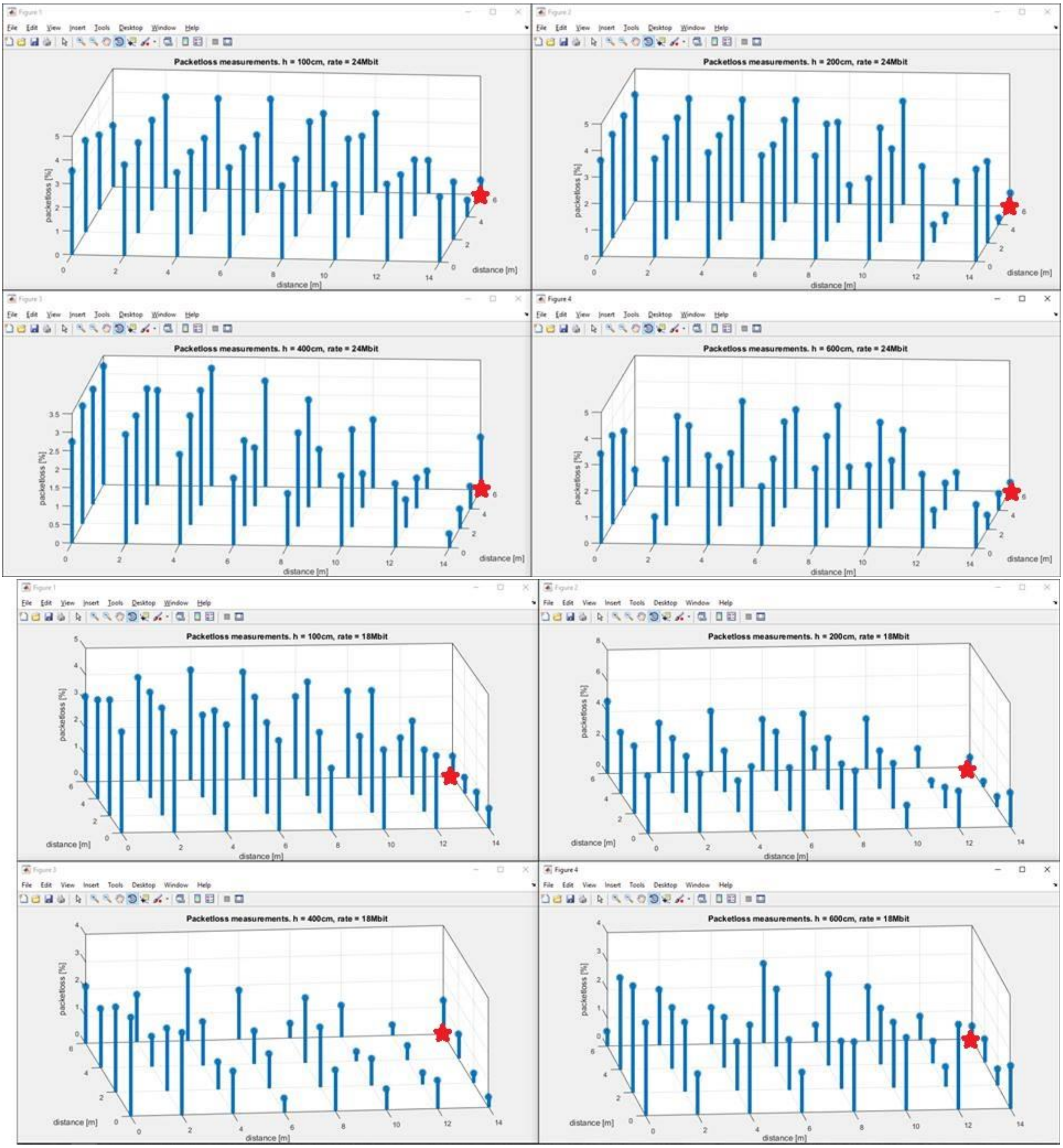
The next table shows the percentwise correlation between packetloss in 2 receivers. I.e. cell (i,j) shows the amount of packets (ratio) that they both lost out of the total number of unique packets they lost combined

$$cell(i,j) = \frac{\#of\ unique\ packets\ lost\ in\ both\ i\ and\ j}{\#of\ unique\ packets\ lost\ in\ i\ and\ j\ combined}$$

12M:

1	0.26791	0.21662	0.40744	0.13924	0.18632	0.13097	0.1522	0.21168	0.17512	0.08596	0.088918	0.07513	0.11082	0.348	0.11544
0.26791	1	0.51359	0.1634	0.27763	0.1432	0.3311	0.35825	0.12785	0.16894	0.16575	0.1464	0.13563	0.13656	0.41807	0.27609
0.21662	0.51359	1	0.1458	0.23714	0.11824	0.28571	0.33187	0.10192	0.12889	0.14645	0.176	0.16939	0.1355	0.33216	0.18653
0.40744	0.1634	0.1458	1	0.089528	0.12039	0.084246	0.13371	0.15635	0.12075	0.051323	0.055891	0.044562	0.074981	0.26845	0.074576
0.13924	0.27763	0.23714	0.089528	1	0.17574	0.30033	0.23059	0.14486	0.19718	0.24405	0.21687	0.19512	0.17972	0.18551	0.25839
0.18632	0.1432	0.11824	0.12039	0.17574	1	0.18047	0.14534	0.33065	0.22507	0.175	0.18605	0.14055	0.25791	0.23133	0.1875
0.13097	0.3311	0.28571	0.084246	0.30033	0.18047	1	0.30702	0.15642	0.21603	0.26667	0.23631	0.23582	0.18801	0.19478	0.32301
0.1522	0.35825	0.33187	0.13371	0.23059	0.14534	0.30702	1	0.1289	0.14354	0.18939	0.20259	0.18818	0.13911	0.23761	0.25513
0.21168	0.12785	0.10192	0.15635	0.14486	0.33065	0.15642	0.1289	1	0.23611	0.1466	0.13636	0.12832	0.22299	0.28918	0.14493
0.17512	0.16894	0.12889	0.12075	0.19718	0.22507	0.21603	0.14354	0.23611	1	0.20712	0.14713	0.13811	0.16169	0.18786	0.20438
0.08596	0.16575	0.14645	0.051323	0.24405	0.175	0.26667	0.18939	0.1466	0.20712	1	0.21774	0.23729	0.20419	0.11532	0.20522
0.088918	0.1464	0.176	0.055891	0.21687	0.18605	0.23631	0.20259	0.13636	0.14713	0.21774	1	0.26506	0.24601	0.11006	0.20588
0.07513	0.13563	0.16939	0.044562	0.19512	0.14055	0.23582	0.18818	0.12832	0.13811	0.23729	0.26506	1	0.20909	0.10032	0.19697
0.11082	0.13656	0.1355	0.074981	0.17972	0.25791	0.18801	0.13911	0.22299	0.16169	0.20419	0.24601	0.20909	1	0.17851	0.19828
0.348	0.41807	0.33216	0.26845	0.18551	0.23133	0.19478	0.23761	0.28918	0.18786	0.11532	0.11006	0.10032	0.17851	1	0.1497
0.11544	0.27609	0.18653	0.074576	0.25839	0.1875	0.32301	0.25513	0.14493	0.20438	0.20522	0.20588	0.19697	0.19828	0.1497	1

In the following 3 figures we show the packet loss at receivers relative to the drone for different rates and heights of the drone. Again, the packetloss (percentage this time) is averaged over 1 minute. The figures shows measurements from 32 receivers, because results from two tests have been joint. The distance from the drone is still accurate on the graph. The only caveat is that the receiver at (x,y) is the same as the receiver at (x+8,y) and that the results are measured at two different times. Otherwise, the figures should be self-explanatory.


Packetloss measurements. h = 100cm, rate = 24Mbit
Packetloss measurements. h = 200cm, rate = 24Mbit
Packetloss measurements. h = 400cm, rate = 24Mbit
Packetloss measurements. h = 600cm, rate = 24Mbit
Packetloss measurements. h = 100cm, rate = 18Mbit
Packetloss measurements. h = 200cm, rate = 18Mbit
Packetloss measurements. h = 400cm, rate = 18Mbit
Packetloss measurements. h = 600cm, rate = 18Mbit
packetloss [%]
distance [m]

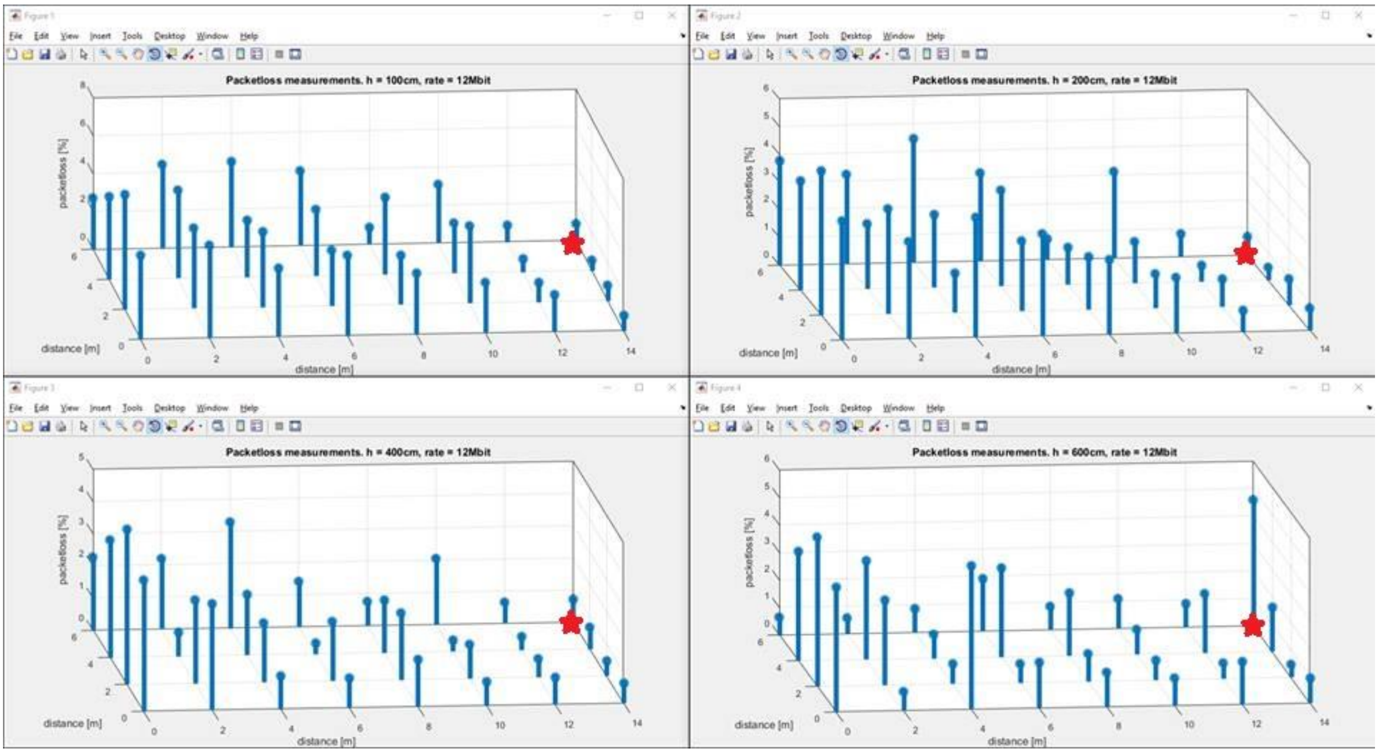


Figure 1
File Edit View Insert Tools Desktop Window Help
Packetloss measurements. h = 100cm, rate = 12Mbit
packetloss [%]
distance [m]
distance [m]
Figure 2
File Edit View Insert Tools Desktop Window Help
Packetloss measurements. h = 200cm, rate = 12Mbit
packetloss [%]
distance [m]
distance [m]
Figure 3
File Edit View Insert Tools Desktop Window Help
Packetloss measurements. h = 400cm, rate = 12Mbit
packetloss [%]
distance [m]
distance [m]
Figure 4
File Edit View Insert Tools Desktop Window Help
Packetloss measurements. h = 600cm, rate = 12Mbit
packetloss [%]
distance [m]
distance [m]