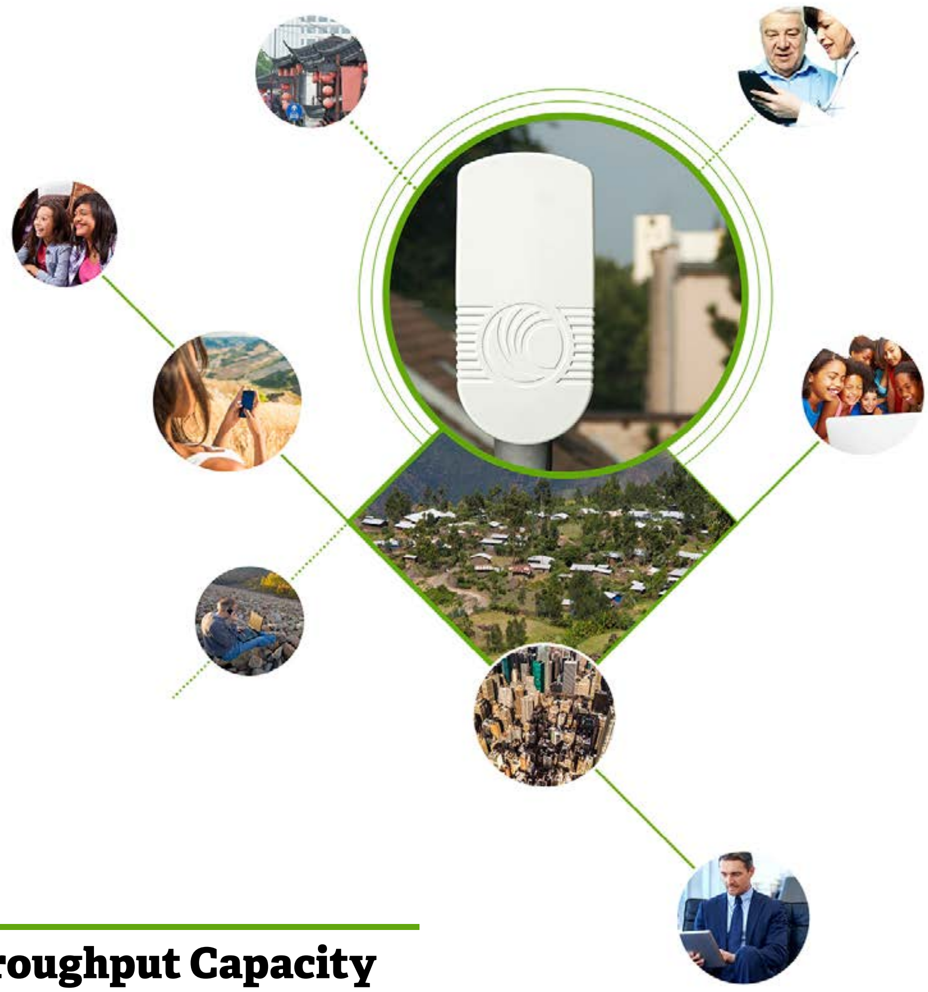
Cambium Networks™



ePMP™

Understanding ePMP Throughput Capacity

Contents

1.0 Purpose

The purpose of this document is two-fold. The first is to describe the two Point to Multi-Point (PMP) modes of operation for the ePMP1000. The second is to explore the execution of typical PMP sector throughput capacity test for each mode of operation, and the interpretation of the results.

2.0 Abstract

For PMP sectors, the ePMP1000 system supports two modes of operation: TDD GPS Synchronized and non-TDD Unsynchronized.

TDD GPS Synchronized:
The TDD GPS Synchronized mode of operation on the ePMP1000 system utilizes a time division duplex (TDD) frame structure to enable highly scalable networks with predictable frequency reuse, predictable performance, and a high level of spectral efficiency. This TDD structure requires a fixed downlink (DL) sub-frame duration, a fixed uplink (UL) sub-frame duration, and hence a fixed DL to UL allocation (throughput) ratio in order to maintain synchronization across the network. This DL to UL ratio is set based on the traffic profile demands across the subscribership and set by the network operator.

Non-TDD Unsynchronized:
The non-TDD Unsynchronized mode of operation on the ePMP1000 system does not utilize a TDD structure. Here the DL durations and the UL durations are determined based on each sectors' demands as they change over time. At one snapshot in time, the sector can favor DL in scheduled resource allocations, and at another it can favor UL. Hence the DL to UL ratios are flexible, not fixed, and cannot be synchronized across the network. Taking spectral efficiency into account this type of system cannot scale predictably. The common name used for this mode of operation on the ePMP1000 is the 'flexible DL to UL ratio" mode.

Throughput tests that are conducted on sectors using tools like iPERF, jPERF or SPEEDTEST can yield different individual peak DL and UL throughput results depending on the mode of operation used on the ePMP1000. However, the actual aggregate sector throughput capacity is the same regardless of the mode and will be explained in this paper.

3.0 Sector Throughput

Before detailing sector throughput capacity tests for the ePMP TDD GPS Synchronized links and the ePMP non-TDD Unsynchronized links, throughput tests and sector throughput/capacity metrics must be understood at the individual station (STA) level. Specifically, when conducting throughput tests at the individual station (STA) level, sector throughput capacity is reached and <u>is equal to</u> the throughput that occurs when all of the available data frame times are used up for the duration of the test. Ultimately, this is the maximum throughput (capacity) that the sector can simultaneously deliver by way of DL and UL throughput concurrently.

Using only the isolated DL throughput test rate or only the isolated UL throughput test rate provides only a partial view of the individual STA and sector capacity. This is especially true when a specified portion of the time is dedicated for DL and a specified portion of time is dedicated for UL, as in TDD; the full throughput of the sector is realized and demonstrated only when both of the dedications, DL and UL TDD sub-frames, are utilized simultaneously to engage all of the data frame times. Alternatively, sector throughput capacity in a TDD system can be determined by adding the DL throughput and UL throughput as run independently and individually. A single direction test, DL or UL, only demonstrates the peak throughput in that direction.

For a flexible DL to UL ratio system, as in non-TDD Unsynchronized mode, sector capacity can be nearly achieved and demonstrated when running a peak DL test or a peak UL test since most of the data frame resources are utilized in either DL or UL based on demand. Alternatively, a test could be run with DL and UL data running simultaneously. In this later test, adding the DL and UL throughput rates would equate to the sector capacity.

Therefore, if comparing capacity in a flexible DL to UL ratio architecture and a GPS synchronized TDD architecture one must use the sector throughput capacity definition given above. This is the true representation of sector capacity and includes what any user can achieve in terms of aggregate throughput in both DL and UL directions of data flow. This is also true when multiple STAs are used for a capacity test.

Specific details for throughput tests are provided in the following sections.

3.1 ePMP-TDD GPS Synchronized Sector Throughput

The configurable DL to UL ratios supported in release 1.0 of ePMP1000 are 75%, 50%, and 30%. These ratios were selected in the design to offer the most common traffic profiles for DL centric, balanced, and UL centric data demands, all based on Cambium's long history in designing and deploying fixed wireless broadband networks under the Canopy and Cambium brands. With Software Release 1.2.3 December 2013, ePMP1000 supports a dynamic DL to UL ratio mode of operation for PMP systems that do not require synchronization and immediate efficient scalability.

Today, with a 75% DL to UL ratio, the maximum DL throughput achievable by a user is 84Mbps in a 20 MHz channel. In this same mode, the concurrent UL peak throughput achievable is 24Mbps. Although this amount of dedicated throughput may be useful in a sector with few users or in a backhaul application, today there aren't any practical PMP applications where a user would commandeer 84Mbps (or more) of throughput for a sustained period of time.

A diagram of the ePMP1000 frame structure with throughput illustrations are shown below in Figure 1 for a 75% DL to UL ratio. As the DL to UL ratio is changed, the total data frame resources remains the same but are shifted according between the DL and UL. Consequently the throughput achievable is shifted between the DL and UL but the total throughput capacity remains nearly the same as depicted in Table 1.

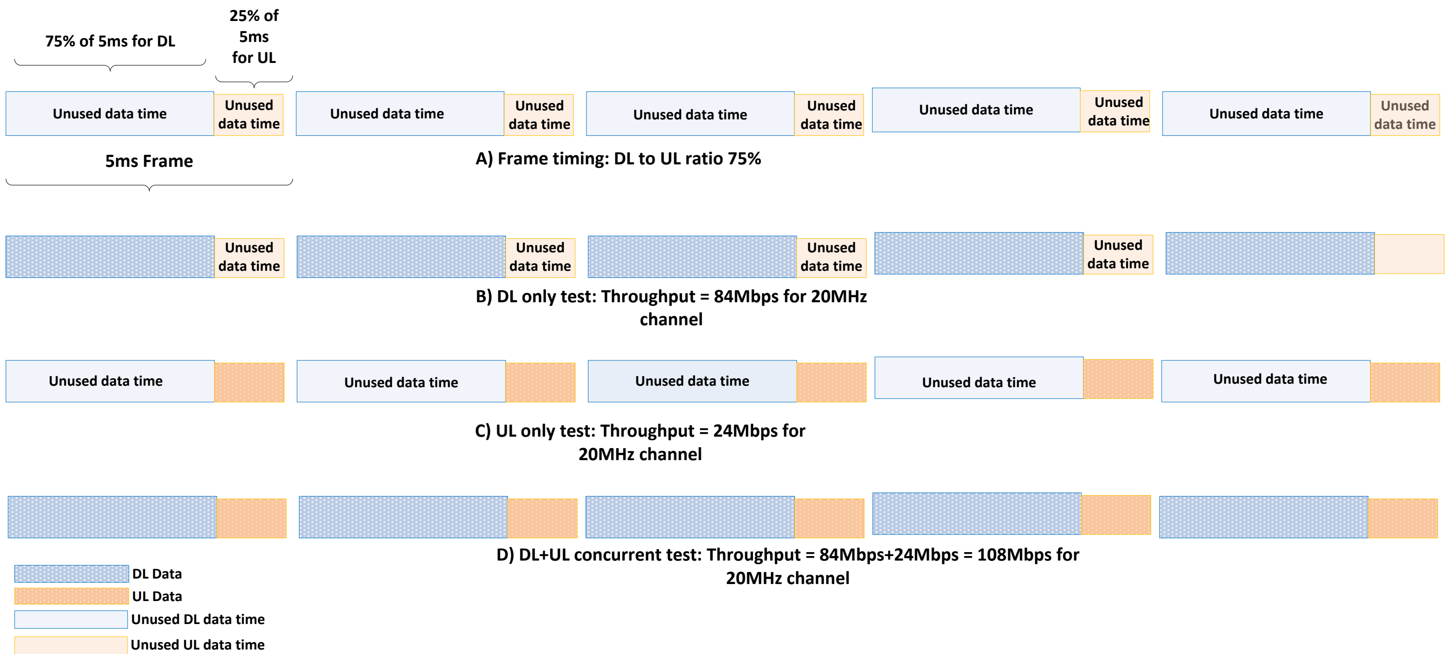


Figure 1. ePMP GPS TDD Synchronized Frames
A) Frame structure for 75% DL to UL ratio; B) DL only test; C) UL only test;
D) DL + UL concurrent test

3.1.1 SINGLE USER SECTOR DL ONLY THROUGHPUT TEST

Depicted in Figure 1B above, with a configured 75% DL to UL ratio, a DL only test that is run using a tool like IPERF or JPERF to find the peak DL throughput capacity of the sector will yield approximately 84Mbps. With this test, nearly 25% of the data frames, the ones allocated for UL traffic, will be practically unutilized. This test only demonstrates the peak DL capability of the user and sector.

3.1.2 SINGLE USER SECTOR UL ONLY THROUGHPUT TEST

For this same 75% DL to UL configuration and same test configuration but running only UL data, only the peak achievable UL throughput is demonstrated. This yields about 24Mbps. The remainder of the frames (75%) will be unutilized here as depicted in Figure 1C.

3.1.3 SINGLE USER SECTOR TESTS USING SPEEDTEST

Using a tool like SPEEDTEST is quite different than IPERF and JPERF. The SPEEDTEST tool sequentially reports both DL and UL throughput results during a single run. Hence the throughput capacity here for the ePMP1000 TDD GPS Synchronized system is the reported DOWNLOAD SPEED and reported UPLOAD SPEED added together.

3.1.4 TRUE THROUGHPUT SECTOR TESTS: CONCURRENT DL AND UL THROUGHPUT

In a bi-directional throughput test with concurrent DL and UL streams, as illustrated in Figure 1D, all of the DL and UL sub-frames are utilized every frame as in a real PMP system where a user(s) accesses both the DL and UL of the sector's capacity. This test runs downlink data from above the AP to a device below the STA and, concurrently, UL data from below the station to a device above the AP. Here the total achievable data throughput across all the frames in a 1 second period is approximately 108Mbits: the sum of the data in the DL sub-frames and the sum of the data in the UL sub-frames. Throughput performance for the other supported DL to UL ratios is depicted below in Table 1. The important point to take away here is that in a TDD system, the total throughput resources available are split at a fixed ratio between the DL and UL sub-frames based on the DL to UL ratio configured. The full throughput resources of the sector are a summation of the DL and UL throughput rates. This can be concurrent throughput or throughput run individually for DL and UL and then summed.

DL to UL Ratio	DL Throughput (Mbps)	UL Throughput (Mbps)	Sector or Single User Aggregate Throughput (Mbps)
75/25	84.2	24	108.2
50/50	54.8	53.5	108.3
30/70	31.2	77.3	108.5

Table 1. Throughput performance vs fixed DL to UL ratios

3.2 ePMP non-TDD Unsynchronized Sector Throughput (flexible DL to UL ratio mode)

At a high level, for a single STA sector, the non-TDD Unsynchronized system allocates the DL to UL ratio based on the load presented. Hence, a test engineer filling the data pipe in the DL without overloading will occupy all of the data resources of the sector just for DL - apart from the required control and signaling in the UL. Likewise, a test engineer filling the data pipe in the UL direction will occupy all of the data resources of the sector just for UL - apart from the required control and signaling in the DL. This is illustrated in Figure 2 below.

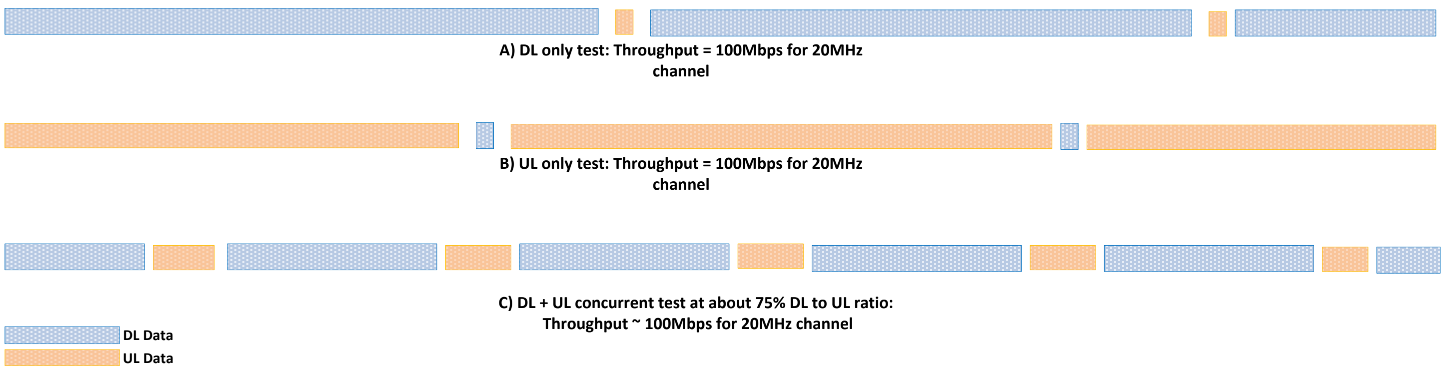


Figure 2. Frame Structure for non-TDD Unsynchronized mode (flexible DL to UL ratio): A) DL only, B) UL only, and C) concurrent DL+UL

3.2.1 SINGLE USER SECTOR DL ONLY THROUGHPUT TEST

In the case of the flexible DL to UL mode of the ePMP1000, running a DL test on a single STA sector using tools like iPerf or jPerf, the throughput reported is the throughput of the sector while allocating all resources for DL data and very little time for UL data. Hence running a DL test this way with a 20MHz channel will yield a throughput level near 100Mbps. As illustrated in Figure 2A above, any UL user data will reduce the DL data throughput rate at a ratio of about 1Mpbs:1Mbps. In this case, the throughput demonstrated is not just the peak capacity of the DL, it is also the actual capacity of the sector since all of the data frame times are utilized.

3.2.2 SINGLE USER SECTOR UL ONLY THROUGHPUT TEST

Conversely if running an UL test on a single STA sector with the flexible DL to UL ratio mode using tools like iPERF or jPERF, the throughput reported is the throughput of the sector while allocating all resources for UL data and very little time for DL data. Hence running an UL test this way with a 20MHz channel should yield a throughput level near 100Mbps all allocated to the UL. Again in this case, this is not just the peak capacity of the UL, it is the actually near the capacity of the sector since the entire data frame times are utilized as depicted in Figure 2B above.

3.2.3 SINGLE USER SECTOR TESTS USING SPEEDTEST

If the test engineer uses SPEEDTEST to evaluate the throughput capacity of an ePMP1000 link in flexible DL to UL ratio mode, the results appear different than with uni-directionly run iPERF or jPERF. The throughput reported for DL and UL should not be added up to give the sector capacity. This is due to the facts presented earlier and how the SPEEDTEST tools work. During the DL portion of the SPEEDTEST test, all of the data frame time resources are used and then during the UL portion of the test all of the data frame time resources are used. SPEEDTEST does not run the DL and UL tests concurrently. The total capacity is either the DL throughput report or the UL throughput report.

3.2.4 TRUE THROUGHPUT SECTOR TESTS: CONCURRENT DL AND UL THROUGHPUT

As discussed at the beginning of this section, to understand the actual throughput that a PMP sector can deliver in general, the concurrent throughput delivered in both DL and UL must be summed. For the flexible DL to UL ratio architecture, the sector capacity is nearly equivalent to DL only or UL only with some degradation when running DL and UL simultaneously if summed. This degradation can become more apparent when running TCP data as the TCP acknowledgements (ACKS) start to accumulate.

For the purpose and comparison required of this document, we will conservatively assume no degradation. Hence, the DL throughput achieved with a maximum demand on DL will achieve near 100Mbps, or if the data is run in the other direction only, the UL throughput will be near 100Mbps. However, if both DL and UL are run concurrently, the aggregate or sector throughput achieved will be again near 100Mbps. The actual aggregate achievable will not be the throughput achieved when running DL alone + throughput achieved when running UL alone. The 100Mbps of throughput will be shared between DL and UL. (Note: Frame overhead was not included in this discussion.)

4.0 Use cases for GPS TDD Synchronized mode and non-TDD Unsynchronized mode

Fixed DL to UL ratio mode and flexible DL to UL ratio mode, are each selectable at the ePMP1000 AP configuration page and can be changed accordingly. A network that does not require synchronization and has users that may want to burst at the full capacity of the sector can benefit from the flexible, on demand, DL to UL ratio mode. However, a sector that is part of a large network of planned sectors with limited spectrum will choose the GPS TDD synchronized mode with the same fixed DL to UL ratios across the towers. The ultimate capacity of both is practically equivalent.

5.0 Conclusions

Both the ePMP1000 TDD GPS synchronized system and non-TDD Unsynchronized system utilize time division multiple access (TDMA) to schedule and deliver data over the air to and from their respective users. The ePMP1000 can utilize synchronized TDD frames to organize the TDMA data frames that are dedicated to DL and UL at fixed durations based on a configured ratio. The non-TDD Unsynchronized mode does not organize the TDMA data frames into TDD sub-frames of fixed ratios, and therefore does not support high spectral efficiency with predictability and scalability.

As a consequence of not utilizing TDD sub-frames, a single user can support sustained throughput rates, in UL or DL, unbounded by a DL to UL ratio. The total throughput available to the sector and hence an individual user is about equivalent to the throughput achieved in either the DL or UL. Since all of the TDMA data time slots are occupied during this unidirectional test, its throughput in DL or UL is nearly equivalent to the throughput achieved if running a concurrent test with DL and UL data to the limit of the link.

With the ePMP TDD sub-frames, a ratio is fixed (e.g., 75%, 50%, or 30%) according to the anticipated user traffic profile. Here the throughput achieved in only one direction, DL or UL, only represents the peak capability in DL or UL respectively. It does not represent the sectors full capacity as the UL sub-frame was left virtually empty during the peak DL throughput test and conversely the DL sub-frame was left virtually empty during the peak UL throughput test. To understand the actual usable throughput that could be reached by the sector and its multitude of user applications, the peak throughputs in the DL only and the UL only must be added together. Another method to compare realistic throughput capacity differences between the flexible and fixed DL to UL ratios is to run a concurrent DL and UL test at a 75% DL to UL utilization rate. In this true comparison for sector and single user capacity, the results yield equivalent performance.