ePMP 3000 vs. LTU

Tests Performed in Partnership with e-vergent and Cambium Networks.

Executive Summary

ePMP 3000 is the latest product in Cambium Networks' ePMP family of products, which is based on 802.11ac Wave 2 technology that supports TX beamforming, MU-MIMO, 4X4 RX and 256-QAM modulation. In the wireless internet service provider (WISP) market, customers are looking for feedback and comparisons of products from different vendors to make appropriate decisions. In many cases, an exact apples-to-apples test is often challenging due to various factors. In this case, Cambium Networks made an attempt to evaluate the ePMP 3000 product line and the latest solution from UBNT Networks, the LTU point-to-multipoint line. While this testing was driven by Cambium Networks, it was done with the support of, and in conjunction with, e-vergent Internet. e-vergent operates throughout Southern Wisconsin and Northern Illinois and operates an extensive fiber and wireless network utilizing various products.

Cambium Networks made all efforts to keep the test methodology and results neutral, but the knowledge of LTU products is certainly limited within the testers and therefore certain tweaks and optimizations may be missing. We have also attempted to explain the technical differences between the products where it made sense. It should be noted that both companies have a strong heritage in wireless. The fundamental difference is likely the approach to achieve spectral efficiency. A radio platform such as LTU with the ability to achieve 1024-QAM is no trivial feat. However, at Cambium Networks, we believe that leveraging multiple input/output technology in MU-MIMO is the way to truly and incrementally achieve higher spectral efficiency.

Our test results showed the following: 1) ePMP 3000 outperformed LTU in both downlink (DL) and uplink (UL) throughput when multiple subscriber modules (SM) are active under different interference conditions. In a clean RF environment, (little to no interference in both DL & UL) ePMP 3000 achieved 200 Mbps in DL and 121 Mbps in the UL while LTU achieved 171 Mbps in DL and 111 Mbps in the UL. 2) LTU outperformed ePMP 3000 in single active SM testing. 3) LTU performance suffered significant UL throughput degradation in ***high interference*** conditions on the access point (AP) (high UL interference) compared to the degradation in ePMP 3000 UL performance; ePMP 3000 UL throughput degraded 49.6% while LTU degraded 92.7%.

Introduction

The two product lines have unique features that do not exist in the other product line. ePMP 3000 supports 802.11ac PHY, MU-MIMO and DL TX beamforming while LTU supports proprietary OTA interface and 1024-QAM. MU-MIMO increases spectral efficiency by a maximum factor equal to the

number of concurrent MU users that the systems supports; in ePMP 3000 the spectral efficiency can be doubled (ePMP 3000 supports two MU users). On the other hand, 1024-QAM increases the spectral efficiency up to 25% (10 bits/symbol compared to 8 bits/symbol for 256-QAM).

To compare which feature set is better in a real-world deployment, with the support of one of Cambium Networks' customers, we built a small live test network with four SMs and compared the performance of both systems. ***We thank our customer for setting up the test network and for helping us execute the test***.

The following sections present the test equipment used, the test network, the test methodology and test results.

Test Equipment:

The test included the following equipment:

Equipment	SW Version	Quantity
Cambium's ePMP 3000 AP	4.4.3	1
Cambium's F300-25 SM	4.4.3	4
Ubiquiti's LTU-Rocket AP	2.0.5	1
Ubiquiti's LTU-Pro SM	2.0.5	4
MikroTik router RB4011iGS+RM	6.45.8	8

Test Network Topology:

The following figure shows the network topology used in the test. It consists of one AP, four SMs and eight MikroTik (MT) routers. Four MT routers were above the AP and one MT router was below each SM. Each MT router behind each SM is configured to communicate with one MT router above the AP. This is required to eliminate the impact of the MT router's processing limits on the throughput when running concurrent throughput tests. The AP and the MT switches above it were connected to a Netonix switch.

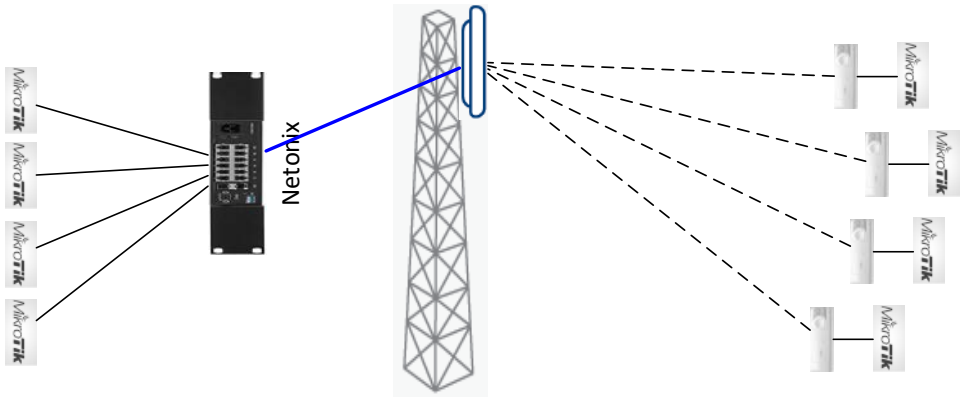


Figure 1: Test Network Topology

Test Network Setup

The LTU & ePMP 3000 APs were mounted on a tower at a 200-foot height. The antennas faced the same direction and had the same downtilt as shown in the below images.

Figure 2: Image of APs on Tower (1/2)

Figure 3: Image of APs on Tower (2/2)

Both APs were connected to a Netonix switch to power up the AP and power down the other AP.

The SMs were placed in strategic locations within line of sight (LOS) to maximize the received signal strength indicator (RSSI). The image below shows the locations of the SMs.

Figure 4: Map of AP and SM Locations

The ePMP F300-25 & LTU-Pro SMs were mounted on a six-foot-high tripod as shown in the picture below.

Figure 5: Image of One of the SMs Mounted on a Tripod

On the ePMP F300-25, we used the eAlign tool to align the SM for the best RSSI. On LTU-Pro SMs, we used the RSSI and rate indicator on the UI to align the SM for the best RSSI and rate.

The SMs' distances from the AP are listed in the following table:

SM	Distance from AP (km)
SM 1	2.2
SM 2	2.15
SM 3	2.3
SM 4	2.2

Throughput Comparison Test Execution

The test was divided into two parts: one ePMP testing part & one LTU testing part. During each part, the following was performed:

- Mounting the SM on the tripod and aligning it for the best RSSI.
- Single-SM throughput test execution. We coordinated among the four locations to execute **one** test a time.
- Multiple-SM throughput test execution. We coordinated among the four locations to execute the test at the same time.
- Throughput captured at the SM UI, AP UI and Netonix switch.

The testing was done utilizing three different frequencies with a 40 MHz channel bandwidth:

- 5180 MHz: very clean channel
- 5230 MHz: moderate UL interference and very low DL interference
- 5800 MHz: high UL interference and moderate DL interference

The following graph shows the spectrum as seen by the LTU devices over the entire band:

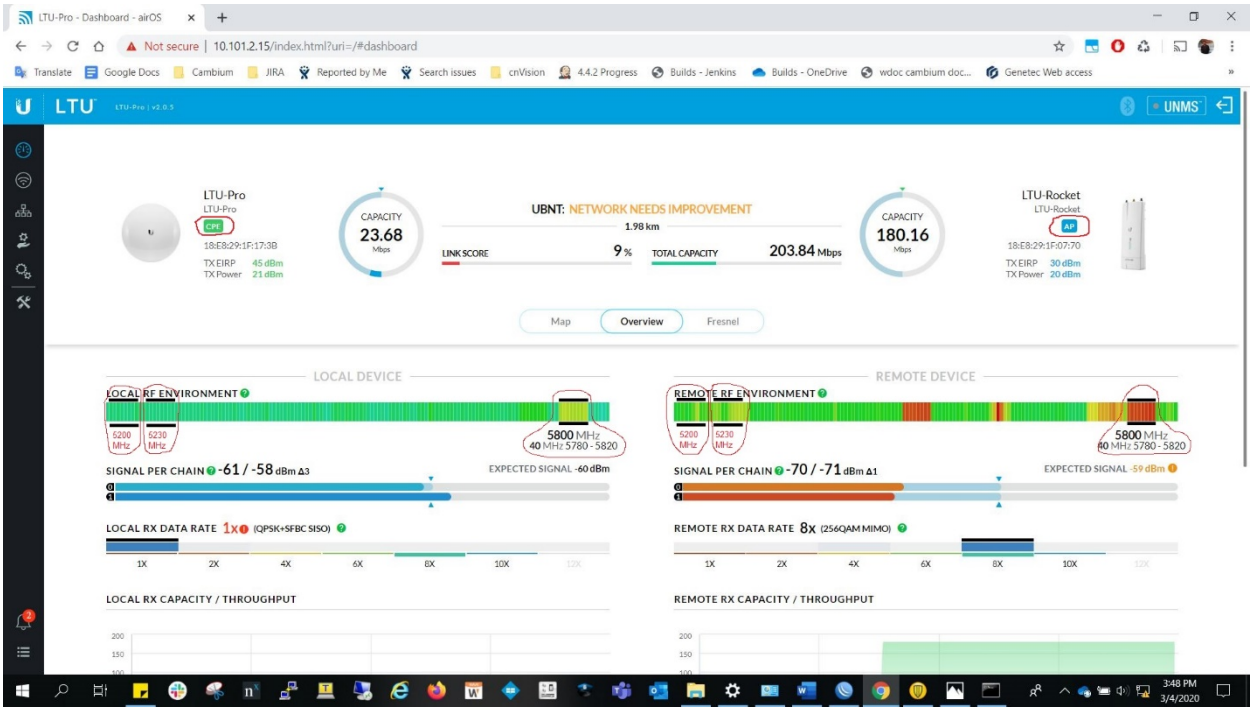


Figure 6: Spectrum Scan as Shown by LTU

Test Results

In all tests, we used the following configuration:

- 5 msec frame duration
- AP TX Power: 20 dBm (both APs)
- LTU-Pro TX Power: 21 dBm
- F300-25 TX Power: Transmit Power Controlled by AP (ePMP 3000's TRL: -55 dBm)*
- 40 MHz
- 50/50: Duty Cycle
- TCP Traffic Testing Using MT Routers

** F300-25 max TX power is 24 dBm at MCS 9 DS for 5180 MHz & 5230 MHz frequencies, 29 dBm at MCS 1 SS for the three frequencies we used in the test. This means in high-UL interference, F300-25 may have had an advantage over LTU-Pro.*

Test 1: Very Low Interference – 5180 MHz

Single SM test:

In a single-SM test, all four SMs were connected, and a throughput test was executed on the SMs one at a time. We ran DL only, then UL only and, finally, bidirectional throughput tests each for a duration of 60 seconds. The below table summarizes the results as reported by the MT router behind the SM.

	MikroTik Throughput (**Single SM**) 50/50 , 40 MHz, 5180 MHz											
	SM 1			SM 2			SM 3			SM 4		
	DL	**UL**	**Bid (DL/UL)**	**DL**	**UL**	**Bid (DL/UL)**	**DL**	**UL**	**Bid (DL/UL)**	**DL**	**UL**	**Bid (DL/UL)**
e3k/F300	28	100	30/70	145	132	94/125	160	130	102/124	113	107	66/96
LTU	165	120	155/120	192	122	180/119	156	116	132/118	164	79	134/78
e3k vs LTU				76%	**108%**	50% / **105%**	**103%**	**112%**	77% / **105%**	69%	**135%**	49% / **123%**

In the above table, SM 1 was not in a good RF condition to achieve a high rate when the ePMP 3000 single-SM test was performed. Then we moved SM 1 to a better location after the single-SM test, and we did not repeat the ePMP 3000 single-SM test due to time constraint. We listed the values here for reference, and we will ignore them from the comparison for the single-SM throughput test case.

As can be seen in the single-SM throughput test, in most cases, the LTU DL performance is higher than ePMP 3000 because LTU supports 10X rate (1024-QAM), and the conditions were good to achieve 10X in the DL (the LTU DL rate was fluctuating between 8X and 10X). ePMP 3000 uses TX beamforming when transmitting to a single user; however, because EIRP at 5180 MHz is 36 dBm, the benefit of TX beamforming of 3 dBm gain is not realized.

For UL, ePMP 3000 is outperforming LTU in both UL-only and bidirectional throughput tests. ePMP 3000 supports four RX chains which gives a 3 dB gain over LTU-Rocket's two RX chains. Additionally, LTU did not achieve 10X in the UL and only achieved 6X or 8X.

Multiple SMs Test:

In the multiple-SMs test, all four SMs were connected, and the throughput test was executed on all SMs at the same time. We ran DL-only, then UL-only throughput tests each for a duration of 60 seconds. The below table summarizes the results as reported by the MT router behind the SM.

	MikroTik Throughput (**Multiple SMs**) 50/50, 40 MHz, 5180 MHz									
	SM 1		SM 2		SM 3		SM 4		Total AP Throughput	
	DL	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**
e3k/F300	45	30	60	32	55	32	40	27	200	121
LTU	42	30	46	30	42	31	41	20	171	111
e3k vs. LTU	**107%**	100%	**130%**	**107%**	**131%**	**103%**	98%	**135%**	**117%**	**109%**

** Total AP Throughput is the sum of individual DL & UL throughputs*

ePMP 3000 is outperforming LTU in both DL & UL throughput. On average, ePMP 3000 DL throughput is ***1.17*** times the LTU DL throughput, and the UL throughput is ***1.09*** times LTU's UL throughput.

Note that ePMP 3000 uses MU-MIMO when multiple users are active and groupable. The total DL throughput of the four SMs (sector throughput) is 200 Mbps compared to 160 Mbps in the single-user case *(SM 3 DL throughput in the single-SM test)*; the extra 40 Mbps is due to MU technology. The LTU single-SM test showed a maximum single-user throughput of 192 Mbps *(SM 2 DL throughput in the single-SM test).* However, with four active SMs, the sector's total DL throughput dropped to 171 Mbps. This shows the advantage of MU-MIMO when the active subscriber count increases; the ePMP 3000 DL throughput increased while LTU's DL throughput dropped with four active subscribers.

Test 2: Moderate Interference – 5230 MHz

In the moderate-interference channel, (5230 MHz) we ran a multiple-SM throughput test only. The results are shown in the table below.

	MikroTik Throughput (**Multiple SMs**) 50/50, 40 MHz, 5230 MHz									
	SM 1		SM 2		SM 3		SM 4		Total AP Throughput	
	DL	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**
e3k/F300	12	25	43	32	70	31	72	26	197	114
LTU	42	20	44	23	41	19	42	20	169	82
e3k vs. LTU	29%	**125%**	98%	**139%**	**171%**	**163%**	**171%**	**130%**	**117%**	**139%**

** Total AP Throughput is the sum of individual DL & UL throughputs*

ePMP 3000 is outperforming LTU in both DL & UL throughput. On average, ePMP 3000 DL throughput is 1.17 times higher than the LTU DL throughput while the ePMP 3000 UL throughput is 1.39 times higher than LTU's UL throughput.

Both APs suffered negligible DL throughput degradation comparable to the 5180 MHz test (~2-3 Mbps, ~1%). DL interference on channel 5230 MHz is almost the same as the DL interference on 5180 MHz (refer to Figure 6 for spectrum scan results).

Both APs suffered UL throughput degradation similar to the 5180 MHz test. ePMP 300 UL throughput dropped 7 Mbps (5.7%) while LTU UL throughput dropped 29 Mbps (26.1%).

Test 3: High Interference – 5800 MHz

In the high-interference channel, (5800 MHz) we ran a multiple-SM throughput test only. The results are shown in the table below.

	MikroTik Throughput (Multiple SM) 50/50, 40 MHz, 5800 MHz									
	SM 1		SM 2		SM 3		SM 4		Total AP Throughput	
	DL	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**
e3k/F300	20	16	3.2	20	10	15	2.5	10	35.7	61
LTU	5	0.6	3	2.5	6	4	1.6	1	15.6	8.1
e3k vs. LTU	**400%**	**2667%**	**107%**	**800%**	**167%**	**375%**	**156%**	**1000%**	**229%**	**753%**

** Total AP Throughput is the sum of individual DL & UL throughputs*

ePMP 3000 is outperforming LTU in both DL and UL throughput. On average, ePMP 3000 DL throughput is ***2.29 times*** higher than the LTU DL throughput while the ePMP 3000 UL throughput is ***7.53 times*** higher than LTU's UL throughput. The 5800 MHz channel has high UL interference at the APs and moderate interference at the SMs as shown in Figure 6.

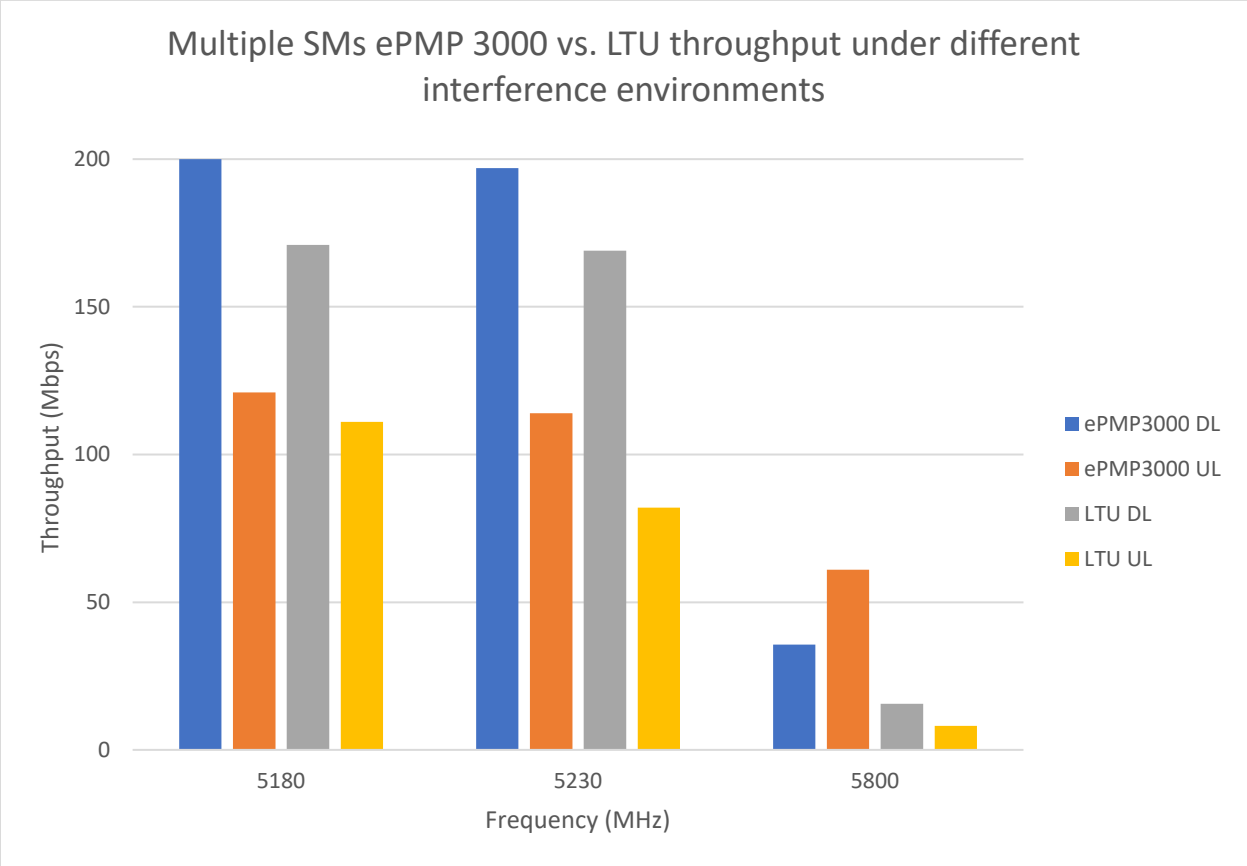
Both APs suffered significant DL throughput degradation compared to 5180 MHz (82% on ePMP 3000 and 91% on LTU). The DL channel condition at the SMs is not very bad, and it should not cause this huge drop. This steep drop was due to the high UL interference which greatly impacted OTA ACKs and TCP ACKs of the DL traffic (in the UL directions).

Both APs suffered significant UL throughput degradation compared to the 5180 MHz test. ePMP 3000 UL throughput dropped 60 Mbps (49.5%) while the LTU UL throughput dropped 102.9 Mbps (92.7%).

Performance Under Interference Comparison

The table below shows a summary of the ePMP 3000 and LTU performance under the three different interference levels.

Frequency (MHz)	Interference		DL		UL	
			ePMP 3000	LTU	ePMP 3000	LTU
5180	None	Throughput (Mbps)	200	171	121	111
5230	DL: None UL: Moderate	Throughput (Mbps)	197	169	114	82
		Throughput Drop % compared with 5180 MHz channel	1.5%	1.2%	5.8%	26.1%
5800	DL: Moderate UL: High	Throughput (Mbps)	35.7	15.6	61	8.1
		Throughput Drop % compared with 5180 MHz channel	82.2%	90.9%	49.6%	92.7%



ePMP 3000 MU-MIMO Gain

In the 40 MHz channel, 50/50 duty cycle, 5 msec frame and four connected SMs, the **maximum** theoretical DL throughput without MU on ePMP 3000 is **160** Mbps. In the ***multiple-SM test***, the ePMP 3000 DL throughput was 200 Mbps on the 5180 MHz channel, which means that MU contributed to at least 42 Mbps of throughput which is a **MU Gain *of at least* 1.25** (MU contributed to at least 25% throughput increase).

The support of 1024-QAM, when constantly achieved, increases sector throughput by a maximum of 25% (1024-QAM = 10 bits/symbol, while 256-QAM = 8 bits/symbol). So, the maximum throughput gain of 1024-QAM is 25% when all SMs are within 1024-QAM distance, while ePMP 3000 MU gain can vary from one to two based on the groupability of the SMs. In large, busy networks, the probability of MU gain higher than 1.25 is high, which means that there is a high probability that ePMP 3000's DL MU technology with 256-QAM offers better performance than LTU's 1024-QAM.

Conclusion

LTU is a good platform with 1024-QAM support and proprietary OTA protocol that, in single active SM testing, matches ePMP 3000 in most cases. But with ***multiple active subscribers,*** ePMP 3000 sector throughput performance outperforms LTU in all interference environments (low/medium/high). In an environment with high UL interference (interference at the AP tower), LTU performance suffered a huge drop in both UL and DL while ePMP 3000 suffered a lower drop compared to LTU. ePMP 3000's DL MU technology with 256-QAM offers better performance than LTU's 1024-QAM. It should be also noted that individual TX performance of the F300-25 and LTU Pro SM were maxed out, but the F300-25 may provide a few dB of extra link budget in the uplink. This combined with the four RX chains may have also provided a benefit to the ePMP 3000. In terms of performance under interference, a lot of work has gone into the ePMP platform over the years in this area, and that may be reflected in the test results. We certainly welcome additional tests from our customers as comparisons like this allow us all to work toward better products and solutions.