Minimum Bit Rate Impact on Outdoor Wi-Fi Network

A Technical Paper prepared for SCTE by

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1. Introduction

The Wi-Fi operates on 2.4GHz and 5GHz which are unlicensed as per FCC (Federal Communications Commission) part 15. Th recent addition of 6GHz gave the Wi-Fi industry many more opportunities to explore. The IEEE formulated the 802.11 standards that became the guidelines for both STA (stations) and AP (Access Point) vendors to be able to design devices that operate on these allocated bands with full compatibility as per other focused bodies like WFA (Wi-Fi Alliance) and WBA (Wireless Broadband Alliance). The clients operating on these bands have basic rates defined. Here are Basic rates for 2.4GHz and 5GHz band:

- The default basic rates (2.4Ghz): 1Mbps, 2Mbps, 5.5Mbps, 11Mbps
- The default basic rates (5GHz): 6Mbps, 12Mbps, 24Mbps

Basic Rates are the most backward compatible rate by which clients and APs can transmit and receive the RF (radio frequency) signals over the air. Typically, the management frames are transmitted at the basic rate defined. The default basic rate for 5GHz is 6Mbps, and for 2.4GHz 1Mbps is the basic rate for DSSS and HR-DSSS and when operating on ERP-OFDM PHY the basic rate is 6Mbps. The management frames will always be sent out at the lowest selected rate. So, selecting the minimum bit rate will help your BSS (basic service set) perform optimally in given RF conditions. As you increase your minimum bit rate, you can see your management frames are now transmitted at higher speed, reducing the management overhead, and minimizing the airtime utilization. This results in higher throughput and reduced cell edge connection, which improves the customer experience.

The biggest challenge on an outdoor Wi-Fi network is to provide a good customer experience for a client throughout its journey. That is, associating to an access point, experiencing high quality content without degraded Wi-Fi experience, and seamlessly transitioning or disassociating from the current access point to another access point nearby or connecting to a cellular network. There are multiple Wi-Fi optimization techniques and adjusting the minimum bit rate or basic rate is one of the techniques.

2. Minimum Bit Rate Lab results

The hypotheses with which the lab test was conducted are as follows:

The change in minimum bit rate (MBR) would impact the management frames, which will help the client to start the open system authentication process at a higher SNR (signal to noise ration) value, which will result in reliable and efficient RF transmissions between the STA and AP. In the case of Wi-Fi to Wi-Fi roaming and Wi-Fi to LTE/cellular roaming, the transition is smoother with MBR if designed for a good overlap.

1. The management frame overhead is reduced which in turn will reduce the channel utilization.
2. The MAC layer boundary of the BSS is now shrunk due to increase in MBR value as MAC (media access control) layer is impacted. The PLCP (physical layer convergence procedure) PHY frame is not impacted as this is always transmitted at 1Mbps for 2.4GHz and 6Mbps for 5GHz.
3. The AP should now report higher SNR and RSSI (hertz) uplink STA statistics and similarly STA will show higher SNR and RSSI values in downlink.
4. The higher SNR should show a shift in the data rates to higher MCS (modulation coding scheme) values as throughput would increase.
5. Reduces sticky client scenarios at the cell edge.

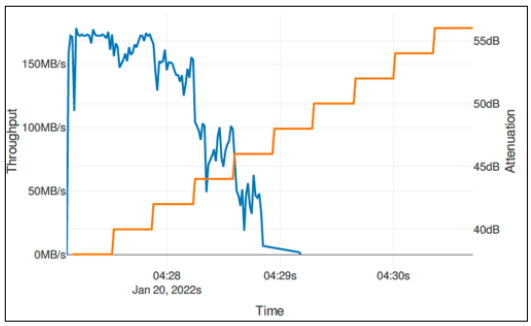
Here is a table that shows the legacy rates and the basic rates.

Table 1 – Legacy Rates and the Basic Rates

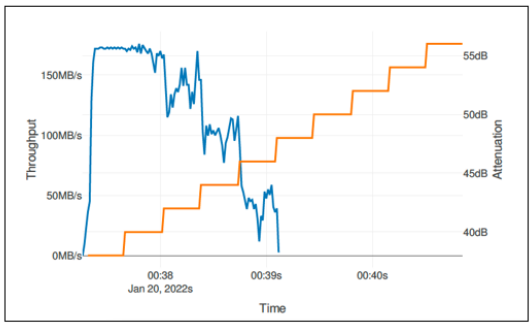
Operating Mode	Legacy Rates (Mbps)	Basic Rate (Mbps)
802.11b	1.2,5.5.11	1,2,5.5,11
802.11b, 802.11n/g	1,2,5.5,11,6,9,12,18,24,36,48,54	1,2,5.5.,11,6,12,24
802.11a, 802.11n/a, 802.11ac	6,9,12,18,24,36,48,54	6,12,24

The goal was to study the 5GHz radio behavior with varied MBR settings, hence Rate Vs Range test was conducted with a STA connecting to an AP with higher MBR value and simulated STA moving away from the AP.

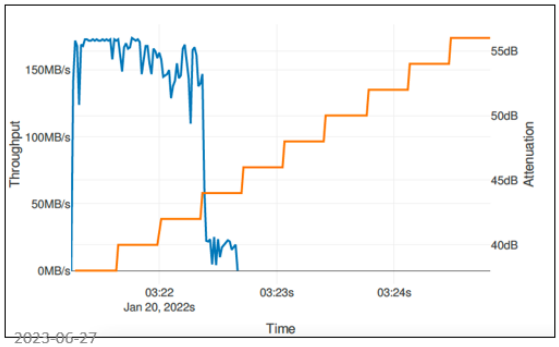
Note: 2.4GHz was turned off and the test was conducted only on 5GHz radios.



6Mbps (MBR)



12Mbps (MBR)



24Mbps (MBR)

Orange line – Attenuation in dBm

Blue line – Throughput in Mbps

Figure 1 - Rate Vs Range Test Results

The observation from the above test was that the sticky client behavior was noted highly in 6Mbps and the stickiness of STA to the AP reduces as the MBR value increases. This helps remove the lower rates at the cell edge, improving data rates, reducing retransmission over the air, and minimizing the airtime utilization.

Here is the table that shows the MCS rate shift for different MBR values:

Table 2 – MCS Rate Shift for Different MBR Values

RSSI (dBm)	SNR	6Mbps (MBR)	12Mbps (MBR)	24Mbps (MBR)
-30	57	9	9	9
-69	18	4	4	4
-71	16	4	4	4
-73	14	3	3	2
-75	12	2	2	
-77	10	1	1	
-78	9	1		

3. Minimum Bit Rate Field Trials

The test methodology included stationary and walk tests out in the field where Comcast outdoor APs are installed.

Two mobile devices along with Ekahau and Aircheck G2 and a few other applications were utilized during this test. We selected the following test locations based on client density and classified them into urban and suburban areas.

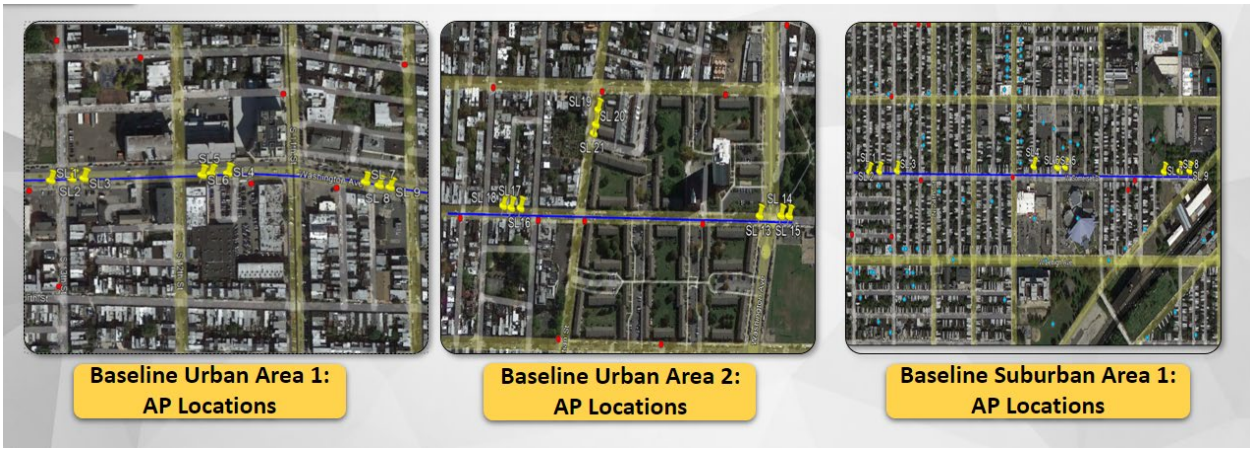


Figure 2 - MBR Field Test locations

3.1. MBR Urban Area field trial

Here is the summary of tests conducted in the urban areas. The metrics that were measured are listed below, and with a change in the MBR value you could see a gradual shift in the metrics.

Table 3 – MBR Urban Area Field Trial

Phase	MBR06		MBR12		MBR24	
	Overall	Outdoor APs	Overall	Outdoor APs	Overall	Outdoor APs
Average RSSI	-68.53dBm	-67.05dBm	-68.59dBm	-68.00dBm	-64.18dBm	-62.66dBm
Average Wi-Fi DL	42.72Mbps	56.53Mbps	23.03Mbps	26.75Mbps	41.29Mbps	51.57Mbps
Average SNR	21.31dB	21.60dB	20.34dB	25.00dB	22.06dB	25.6dB
nPerf DL	18.3Mbps	26.7Mbps	11.5Mbps	11.1Mbps	26Mbps	33.6Mbps
nPerf UL	5.5Mbps	7.9Mbps	3.6Mbps	4.0Mbps	9Mbps	12.2Mbps
YouTube Streaming%	95.4%	95.2%	92.37%	94.3%	96.73%	98.74%
Sample	11691	7392(62.7%)	11067	6755(61%)	9994	6502(65.1%)
>MCS 2 RSSI Threshold (>=-76dBm)	75.12%	78.8%	80.69%	73.21%	94.6%	95.3%
Wi-Fi Disconnected% | LTE %	3.8% | No LTE		1.7% | No LTE		2.13%| No LTE	

3.1.1. RSSI VS Throughput Scatter Plot

For MBR12 and MBR24 the scatter plot shows lower samples of connected clients below -80dBm RSSI values and have higher downlink speeds reported.

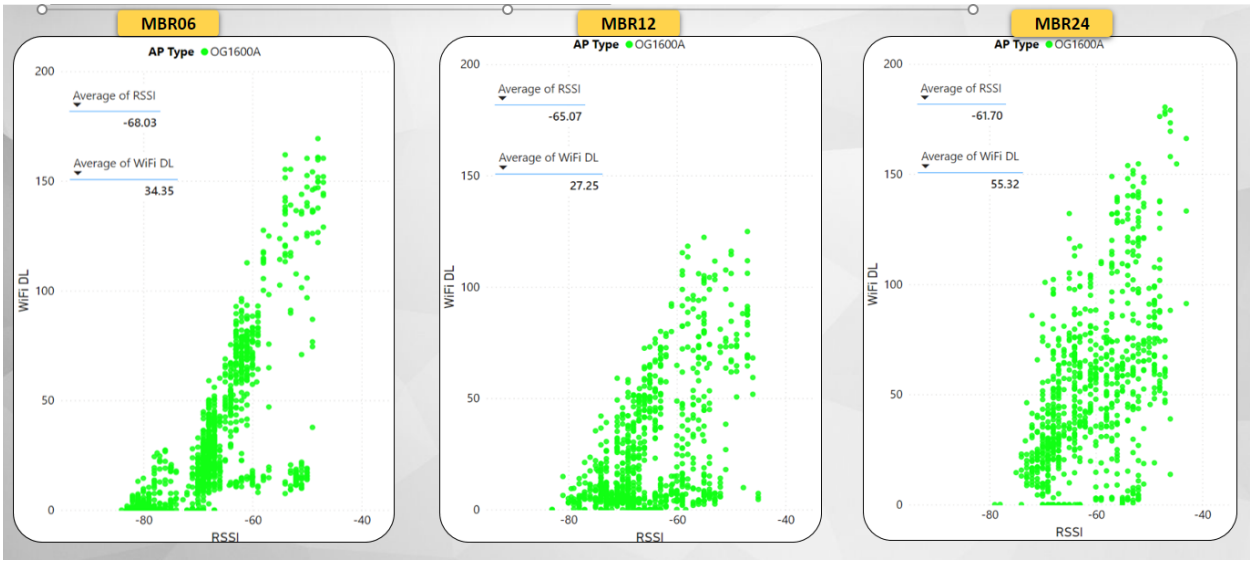


Figure 3 – Urban RSSI vs Throughput Scatter Plot

3.1.2. Ekahau Plot – Signal Strength

Figure 4 – Urban Ekahau Plot – Signal Strength

3.1.3. Ekahau Plot – SNR

Figure 5 – Urban Ekahau Plot - SNR

Key takeaways of implementing MBR in an Urban area are as follows:

1. The number of samples with low RSSI connected to outdoor was reduced during MBR 24 testing.
2. During MBR24, a lower number of samples observed at RSSI<-75dBm.
3. MBR24 showed 77% samples above 10Mbps, compared to 57% in MBR12 testing.
4. Coverage and SNR improved during MBR24.
5. The YouTube media quality on HD 1440 improved on MBR 24 testing.

3.2. MBR Suburban area field trial

Here is the summary of tests conducted in suburban areas. When compared to urban areas, we see few variations; this is due to the RF condition in the location, the client density, and the distribution of indoor and outdoor APs.

Table 4 – MBR Suburban Area Field Trial

Phase	MBR06		MBR12		MBR24	
	Overall	OG1600 APs	Overall	OG1600 APs	Overall	OG1600 APs
Average RSSI	-67.3dBm	-67.83dBm	-68.76dBm	-70.24dBm	-68.95dBm	-71.27dBm
Average Wi-Fi DL	34.3Mbps	44.65Mbps	25.5Mbps	37.12Mbps	19.98Mbps	24.58Mbps
Average SNR	18.8dB	20dB	18dB	21dB	18.08dB	16.4dB
nPerf DL	12.4Mbps	10Mbps	16.5Mbps	17.2Mbps	13.6Mbps	11.6Mbps
nPerf UL	5.1Mbps	7.4Mbps	4.7Mbps	7.2Mbps	3.8Mbps	4.3Mbps
YouTube Streaming%	99.6%	99.08%	96.6%	95.14%	94.97%	97.22%
Sample	10054	5037(50%)	9515	3867(40.6%)	9530	3733(39.2%)
>MCS 2 RSSI Threshold (>=-76dBm)	88.4%	82%	85.27%	75%	84.17%	77.5%
Wi-Fi Disconnected% | LTE %	115(1.1%)		160(1.6%)		198(2.0%)	

3.2.1. RSSI VS Throughput Scatter Plot

From the scatter plots it appears that the MBR6 shows better throughput and samples below -80dBm, unlike the urban area.

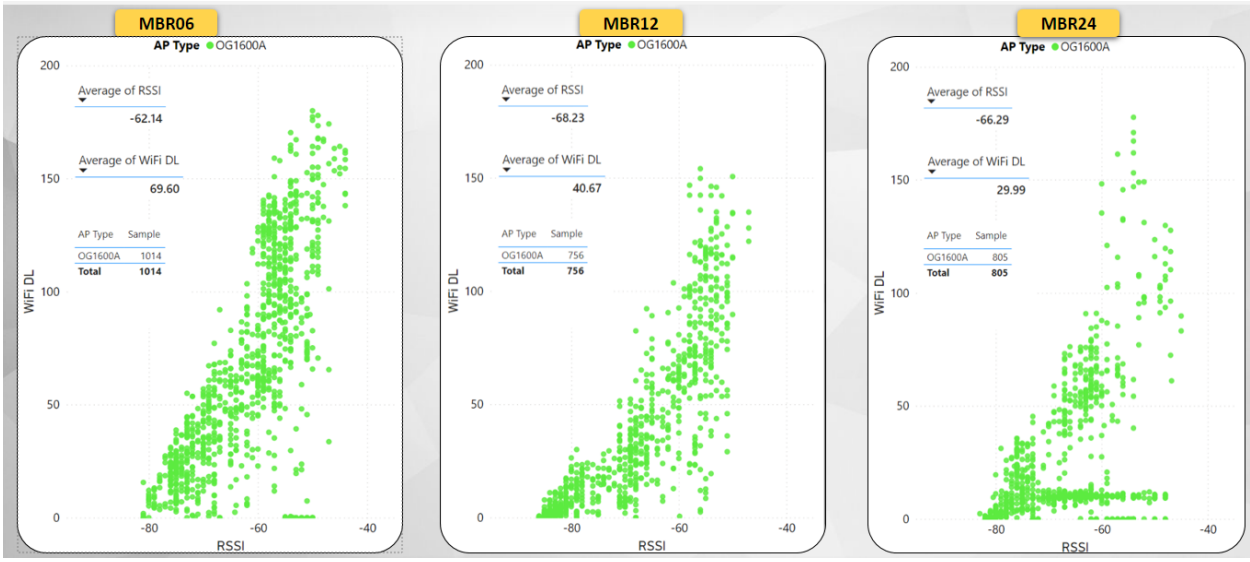


Figure 6 – Suburban RSSI vs Throughput Scatter Plot

3.2.2. Ekahau Plot – Signal Strength

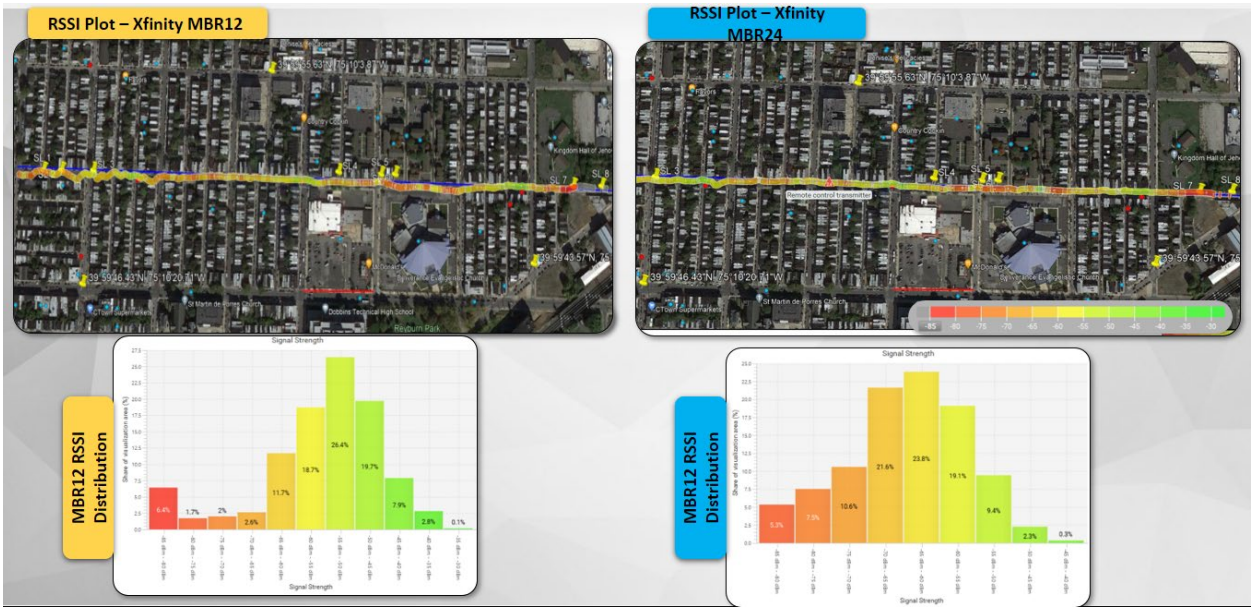


Figure 7 – Suburban Ekahau Plot – Signal Strength

3.2.3. Ekahau Plot – SNR

Figure 8 – Surburban Ekahau Plot – SNR

Key take aways from the Suburban field test are as follows:

1. The MBR6 or MBR12 values provided better results when compared to MRB24.
2. The samples on MRB24 have lower count compared to MBR12 but the difference is less than one percent.
3. Down load average was higher in 6Mbps compared with other MBR values.
4. Youtube streaming was high and at 6Mbps MBR value.
5. The DL throughput when MBR6 or MBR12 was set was higher than MBR24 configuration.
6. The SNR and RSSI distribution were better when MBR12 was set when compared to MBR24

4. Conclusion

The Outdoor Wi-Fi network has many variables that would constantly change the RF environment. Some of them can be controlled and are predictable, but most of the variants need constant observation and testing. Hence, to optimize such a network, we need multiple telemetry from the field and from Wi-Fi metrics. MBR would be one of the techniques that would help the client connection; based on your requirements and the RF environment you can have varied MBR settings to achieve your requirements. In our Urban testing the results favored 24Mbps as the MBR value, mostly because of the client density and the high AP density. In the Suburban testing, the results favored 6Mbps and 12Mbps as the MBR values, mostly because the APs are distributed and no Wi-Fi overlaps.

Additional study is needed to understand the 2.4GHz and 6GHz band and its impact with the MBR settings. The 5GHz study was conducted with bandwidth set to 40Mhz, hence for 20MHz and 80MHz design additional testing is required as the noise floor would vary with channel bounding which will impact other Wi-Fi metrics.

Abbreviations

AP	Access Point
BSS	Basic Service Set
DL	Down Link
FCC	Federal Communications Commission
HD	High Definition
IEEE	Institute of Electrical and Electronics Engineers
MAC	Media Access control
MBR	Minimum Bit Rate or Minimum Basic rate
MCS	Modulation Coding Scheme
PHY	physical layer
PLCP	physical layer convergence procedure
RF	radio frequency
RSSI	Received signal strength indicator
SCTE	Society of Cable Telecommunications Engineers
SNR	signal to noise ratio
UL	up link
WBA	Wireless Broadband Alliance
WFA	Wi-Fi Alliance

Bibliography & References

https://www.fcc.gov/document/5-ghz-unlicensed-spectrum-uniiThe ARRL Antenna Book, 20th Ed.; American Radio Relay League

https://www.cwnp.com/cwap-study-guide404/

https://www.cwnp.com/certifications/cwdp

https://www.ekahau.com/blog/channel-planning-best-practices-for-better-wi-fi/

https://sourceforge.net/arris/og1600/home/Home/

https://documentation.meraki.com/MR/Radio_Settings/Minimum_Bitrate_Control

https://fccid.io/UIDOG1600CT/User-Manual/manual-3227914

