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A New Look at Bluetooth® Density for the Office: Expanded Simulation Results Deliver Real-World Opportunities for Audio Deployments

White Paper by Plantronics

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EXECUTIVE SUMMARY

The promise of workplace mobility, including wireless office technologies such as Bluetooth, offers ways to fast track employee productivity, customer satisfaction, and business innovation. Mobility enables new ways to work more effectively without typical barriers of the office environment. The question is, are you ready?

A recent industry analyst survey of over 1,000 IT decision makers working in US and European businesses revealed that 66% of their companies use smartphones for work and 46% use tablets[1]. In the paradigm shift to workplace mobility and on-the-go connectivity, demand for cordless headsets has significantly increased and is expected to equal corded headset shipments in the next five years[2].

The wireless office landscape offers great business benefits, but challenges, too. IT managers are particularly keen to address density issues across office environments with open spaces, crowded areas or those with ambient noise issues. The degree of density matters when initiating and managing wireless headset environments.

Plantronics' wireless engineers recently designed a real-world simulation model to study Bluetooth behavior under varying conditions, as compared to earlier Bluetooth density data. The model measures and analyzes pertinent impacts to density, and the new findings are impressive. Key takeaways include:

- The study results ensure the most relevant and appropriate Bluetooth density guidance to date due to the specifics of the simulation model. The governing factors include:
  - Number of users in a specified area
  - Volume of calls made per hour
  - Proximity of users to each other
  - Wi-Fi infrastructure, including the presence of zero, one and two Wi-Fi access points in the same office area
- This is the first Plantronics density study that includes the presence of Wi-Fi access points in the analysis, which is crucial given the prevalence of Wi-Fi in office environments today
- New Bluetooth density recommendations show up to a 6X density improvement over the best-case findings for previously Plantronics published density study results associated with earlier generations of Bluetooth technology

This paper furnishes readers with details about the latest findings in achieving maximum Bluetooth density and why they are important.

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[1] Frost & Sullivan's Global Office and Contact Center Headset Market: Headsets Become a Critical UCC Tool, (NBF7-64, February 2013)

[2] Frost & Sullivan's Global Office and Contact Center Headset Market: Headsets Become a Critical UCC Tool, (NBF7-64, February 2013)

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A New Look at Bluetooth Density for the Office: Expanded Simulation Results Deliver Real-World Opportunities for Audio Deployments

INTRODUCTION

Bluetooth® wireless environments offer immense opportunities to improve how people work and ultimately how cost effectively they will operate within the organization. When employees are able to move about their workspaces unencumbered by cords or wires, they can more resourcefully address calls with hands-free flexibility, and have more freedom to collaborate and work as a team. Consequently, the enterprise as a whole benefits from increased productivity, a greater ease of doing business, and boosting the customer experience.

IT leaders considering Bluetooth® wireless technologies are seeking ways to satisfy an increasingly mobile workforce, to simplify office operations and to accelerate workplace efficiencies. Successfully deploying Bluetooth across the enterprise depends on several key factors, such as the number of devices in a location or the coexistence with Wi-Fi access points (APs). Understanding and planning for the potential challenges of wireless headset density, concurrent Wi-Fi environments and other relevant dynamics are critical. Bluetooth density analysis enables IT to fully appreciate the scope and outcome of implementation across the enterprise and to plan appropriately for optimal performance.

WHY DENSITY MATTERS IN BLUETOOTH PLANNING

Density—or user density—is a term used to describe the number of active users who can operate within an area in which their wireless Bluetooth communication devices are sharing the same radio spectrum. Active refers to the person using the headset, to participate in a telephone call or an automatic call distributor in constant "on" mode.

The degree of user density in Bluetooth configurations is important when planning for audio quality within a given space. The planner needs to know if the area designated for Bluetooth headsets will adequately and amply support the desired audio quality and budgetary efficiencies. Calculating density helps to provide an accurate measure of how many Bluetooth wireless devices can actively and simultaneously operate in proximity to each other, or in the presence of other wireless technologies—without interference, or the degradation of RF signals or audio quality. For more details about wireless density, please refer to the **Plantronics Wireless Voice in the Office Environment Whitepaper.**

Key points to consider:

- The presence of other wireless technologies might compete for the same resources. While Bluetooth and Wi-Fi each have different protocols, different signaling structures, they do share the same 2.4GHz radio spectrum.
- Various interference solutions may provide mutually beneficial coexistence while maintaining acceptable performance and reliability. These mitigators are based on time, space or frequency to isolate radios for collocated Bluetooth and Wi-Fi devices. Adaptive frequency hopping (AFH) is a built-in coexistence feature standard in most contemporary devices that scans the operating band for interference and adapts to reduce interference between wireless technologies sharing the 2.4GHz spectrum. As Wi-Fi presence increases, however, AFH will have fewer channels to hop between, thereby impinging on Bluetooth density.
- Density planning must account for the various types of wireless devices and Wi-Fi access points that exist, and how interaction among them may impact Bluetooth headset audio quality. While not all wireless deployments required a site survey, assessing both physical and wireless obstructions can disclose a more accurate feasibility for achieving better Bluetooth density.

PLANTRONICS DIGS DEEPER TO REVEAL NEW INSIGHTS

A leader in wireless headset design, Plantronics is actively engaged in improving the wireless experience for our customers. Recently, we conducted advanced simulation testing of Bluetooth density challenges, both with and without the presence of other wireless technologies in the office environment. The purpose of these simulations was to reevaluate initial claims and previously established real-world limitations for Bluetooth density, which were rightfully conservative. The data now available suggests greater density achievement is possible.

The Plantronics system simulator precisely models Bluetooth behavior under varying circumstances. Our methodology focuses on minimizing audio interference issues posed by collocation of too many Bluetooth devices, and the coexistence of zero, one and two Wi-Fi APs in the same office area. By introducing the presence of Wi-Fi APs into simulations, we can better analyze the caliber of impact that Wi-Fi can have on Bluetooth density.

Our findings are statistically relevant and reveal a much more granular baseline perspective on Bluetooth density guidance than earlier recommendations. The simulation data closely aligns and validates empirical observations occurring in customer environments where Bluetooth headsets are deployed in significant numbers. The results present new opportunities for density planning and the deployment of Bluetooth headsets in higher quantities across the enterprise.

EXAMINING KEY SIMULATION RESULTS FOR THE REAL WORLD

Simulations attempt to imitate the operation of a real-world process or system over time. The basic steps in any simulation study include preliminary analysis, model building, validation, simulation runs, and statistical analysis of output data. A simulation model ought to represent the key characteristics or behaviors of those everyday processes or systems. The collection of data for any model needs to be sufficiently large in order to provide adequate likeness or scope to all types of situations that can occur in that specific scenario.

PLANTRONICS SIMULATION METHODOLOGY

Our Bluetooth simulation model was built upon an enterprise office scenario in which a set of base stations are placed on a grid. A single headset is connected to each base station (1:1 ratio). The connection between a headset and base device forms a wireless Bluetooth network link known as a piconet. Each piconet is independent of another.

Methodologies used in this simulation model were designed to examine connection performance in various states. The headsets were distributed around the base stations in order to monitor transmissions from the base to the headset (downlink) and from the headset to the base (uplink) for each piconet pairing. Locations, timing relationships and propagation conditions were randomly varied and observed to aid in predicting the most likely behaviors that Bluetooth may exhibit under these specified and dynamic circumstances. Physical objects, such as furniture and humans, were factored into the simulation environment to account for any effects they, too, might have on reliability of coverage or deviation of signal performance. These potential obstacles are captured and depicted in the model using a technique known as shadowing or shadow fading.

The following assumptions were made for the simulation model regarding how Wi-Fi affects Bluetooth density:

- Each Wi-Fi access point will support a single Wi-Fi channel spanning 20 MHz
- The Bluetooth AFH procedure will select a part of the frequency spectrum not occupied by Wi-Fi
- Where Bluetooth operates within the frequency band reduces from 79 MHz to 50 MHz for one Wi-Fi AP and from 79 MHz to 20 MHz for two Wi-Fi APs

PLANTRONICS SIMULATION OUTPUT

To fully appreciate how the density simulation results will be applicable to enterprise deployments of Bluetooth, it is next necessary to explain simulation output. Because input processes that drive simulation studies tend to be random variables, simulation output is regarded as statistically-based estimations. This being noted, our primary output from the density simulations is a valid set of performance guidelines.

Specifically, the Plantronics simulation output provides guidance as to the amount of area that will be required per Bluetooth headset system/user to achieve acceptable levels of interference-free audio performance. The simulation output is based on the following assumptions and guidelines:

- Acceptable performance is defined as 1% frame erasure/error rate (FER), which is an acceptable level for voice communications
- Acceptable performance includes an outage of 5%, which means that 5% of headsets/users are experiencing poorer than the 1% FER (and 95% of headset users are experiencing a 1% FER or better)
- These FER and outage quotes offer assurance for an outstanding audio quality experience

- The quantity of systems/users in the office environment is taken into account
- The presence of zero, one or two Wi-Fi APs

Simulation output correlating the spacing of the Bluetooth headset base systems to the area guidance above includes:

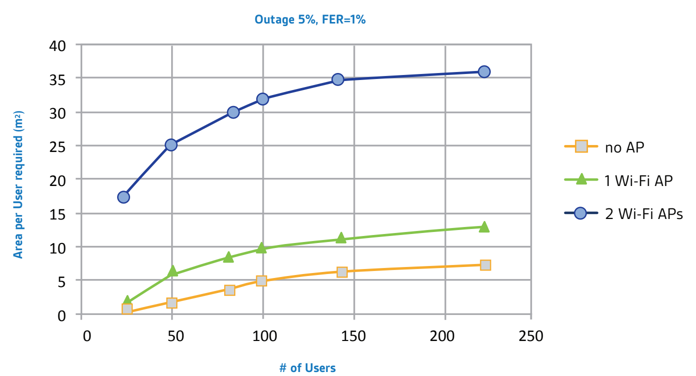
- The quantity of Bluetooth headsets/users varies from 25 to 225

BLUETOOTH DENSITY SIMULATION #1: 100% CALL TRAFFIC LOADING

The first simulation exercises assume a 100% call traffic load, in which all users in each simulation are present and on active calls using Bluetooth headsets paired in a 1:1 ratio to base systems. Simulations were performed with zero, one and two Wi-Fi APs present.

The Bluetooth density simulations performed best without any (zero) Wi-Fi APs present, as depicted by the lower, black curve in Graph 1 below. The area required per active headset/user is significantly below 10 square meters, even as the number of users exceeds 200.

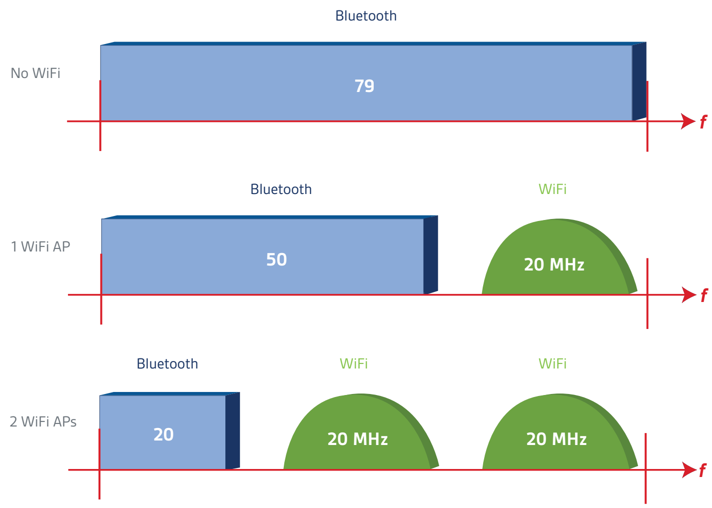
Simulation 1, Graph 1: Bluetooth Only, Impact of One and Two Wi-Fi Access Points = area required per Bluetooth base in m^2



Area required per Bluetooth base, measured in square meters. All Bluetooth devices are Class 2; all devices are at 100% utilization on active calls.

Considering an area of 300 square meters (15m x 20m) for comparison, the area would accommodate approximately 80 users with no Wi-Fi AP present, approximately 50 users with one Wi-Fi AP present, and about 20 users with two Wi-Fi APs present. (See Figure 1.)

Figure 1: Wi-Fi impact on Bluetooth spectrum by Bluetooth AFH, with Zero, One and Two Access Points*.

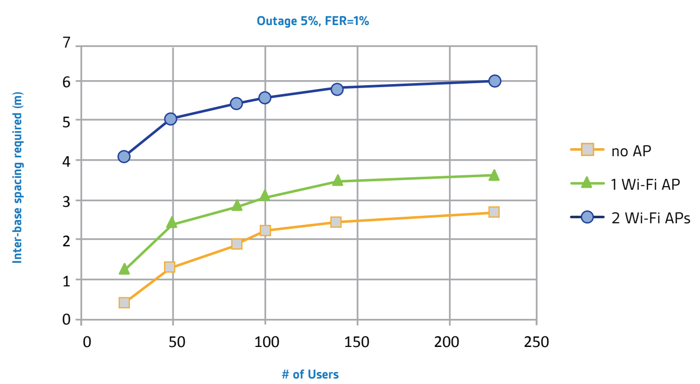


*NOTE: Channel bonding not assumed

An increase in area required per Bluetooth user—or a decrease in density—when Wi-Fi APs are introduced is due to the fact that Bluetooth AFH is actively at work to avoid interference with Wi-Fi communications. With Wi-Fi present, a smaller portion of the spectrum is available to be shared among Bluetooth users. The conclusion is that Bluetooth AFH has an impact on Bluetooth density. (See Tables 1 and 2 in Appendix A for specific references to the graphic plots in square meters and square feet.)

Graph 2 shows the spacing required in meters between Bluetooth base systems, for 100% call traffic loads, with zero, one and two Wi-Fi APs present.

Simulation 1, Graph 2: Bluetooth Only, Impact of One and Two Wi-Fi Access Points = spacing required between Bluetooth bases in meters



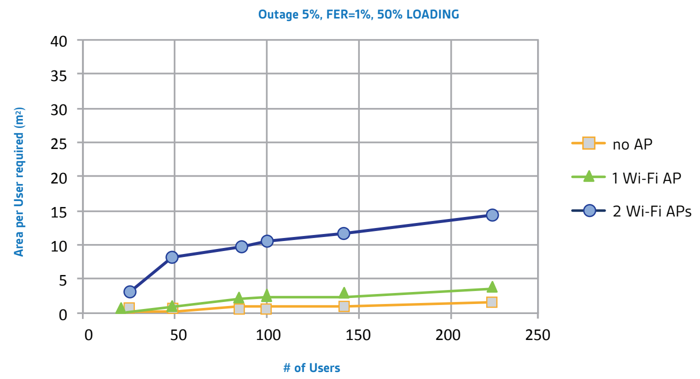
Spacing required between Bluetooth bases. All Bluetooth devices are Class 2; all devices are at 100% utilization on active calls.

(See Tables 3 and 4 in Appendix A for specific references to the graphic plots in square meters and square feet.)

BLUETOOTH DENSITY SIMULATION #2: CALL TRAFFIC LOADING DROPS 50%

The second set of simulation exercises examines the resulting decrease in area and spacing required per Bluetooth headset/user, as a result of dropping the average call traffic loading by 50% (See Graph 3 below.) Using the unit measurements, this equates to 0.50 Erlangs or 18 CCS. Otherwise, Simulation 2 assumes all the same parameters as Simulation 1.

Simulation 2, Graph 3: Same parameters as Simulation 1 with 50% Call Traffic Loading = area required per Bluetooth base in m^2

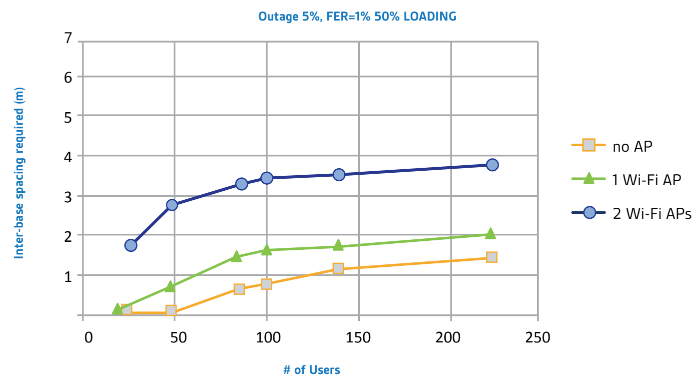


Area required per Bluetooth base. All Bluetooth devices are Class 2; all devices are at 50% traffic on active calls.

(See Tables 5 and 6 in Appendix A for more specific references to the graphic plots in square meters and square feet.)

Graph 4 displays the spacing required in meters between Bluetooth base systems, for 50% call traffic loads, with zero, one and two Wi-Fi APs present.

Simulation 2, Graph 4: Same parameters as Simulation 1 with 50% Call Traffic Loading = spacing required between Bluetooth bases in meters



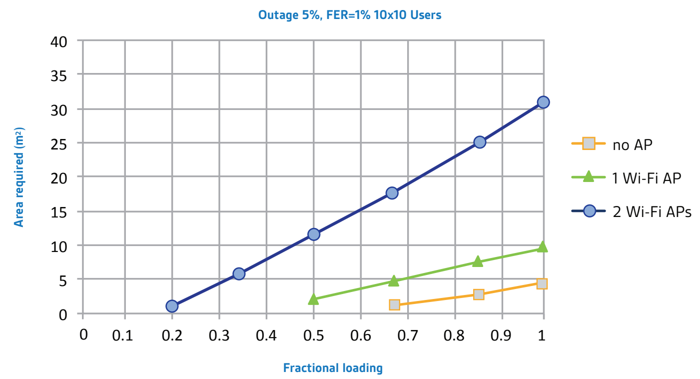
Spacing required between Bluetooth bases. All Bluetooth devices are Class 2; all devices are at 50% utilization on active calls.

(See Tables 7 and 8 in Appendix A for specific references to the graphic plots in square meters and square feet.)

BLUETOOTH DENSITY SIMULATION #3: FRACTIONAL CALL TRAFFIC LOADING

In the final simulation conducted by Plantronics, the average Bluetooth call traffic loading is variable or fractional, with volume fluctuations from 10% to 100%. All the Bluetooth headset/users are on active calls, ranging from 6 minutes per hour to 60 minutes per hour. Simulation 3 comprises a 10x10 user grid for a total of 100 Bluetooth users. For this simulation, we cite call minutes per hour, CCS and Erlangs.

Simulation 3, Graph 5: Variable Call Traffic Loading from 10% to 100%
= area required per Bluetooth base in m^2 100 Users fixed

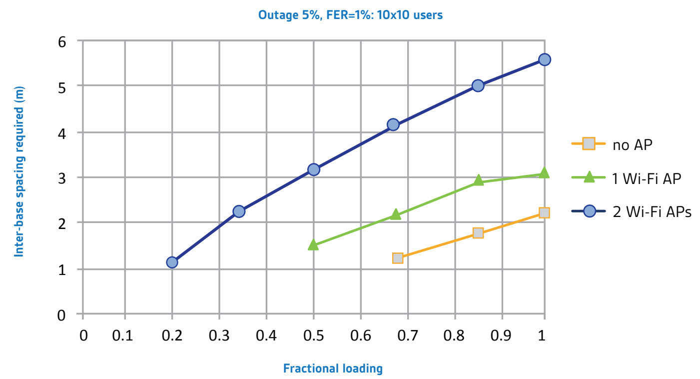


Area required per Bluetooth base, measured in square meters. All Bluetooth devices are Class 2.

(See Tables 9 and 10 in Appendix A for specific references to the graphic plots in square meters and square feet.)

Graph 6 shows the spacing required in meters between Bluetooth base systems, for fractional call traffic loads, with zero, one and two Wi-Fi APs present.

Simulation 3, Graph 6: Fractional Call Traffic Loading from 10% to 100%
= spacing required between Bluetooth bases in meters



Spacing required between Bluetooth bases. All Bluetooth devices are Class 2; users are active and working within a 10x10 grid.

(See Tables 11 and 12 in Appendix A for specific references to the graphic plots in square meters and square feet.)

SIMULATIONS CONCLUSIONS SUMMARY

The Plantronics simulations were designed to emulate, test and analyze Bluetooth headset usage under various real-world conditions, in order to determine the essential criteria for achieving desired density performance. The simulation test results were impressive.

Simulation 1 bore the worst-case call traffic loading at 100%. The conditions of Simulation 2 were met with a still relatively high load of 50% call traffic. In both simulation tests, the figures for Bluetooth density for active headsets/users proved to be far more favorable than previously published density figures associated with earlier generations of Bluetooth technology.

The outcome of Simulation 3 revealed how a typical enterprise office using Bluetooth headset systems would experience density under fluctuating call volume conditions. With a call traffic loading average of approximately 30%, the projections for Bluetooth density became even more favorable, even when one or two Wi-Fi APs were present.

These scientific and statistically-valid results clearly confirm significant improvements in Bluetooth density. Previous user density trials achieved much lower conclusions for effective reach and the number of active headsets before experiencing interference. Over time, Bluetooth density has evolved to become more sustainable so IT managers can deploy Bluetooth headsets in higher quantities in the office environment. Plantronics simulation conclusions afford customers a greater measure of confidence to embark upon larger or more complex Bluetooth implementations in enterprise environments.

FINAL NOTES

New findings for improved Bluetooth density suggest a win-win for office users and business value. Audio devices are an integral part of today's dynamic workplace, and organizations can now capitalize on the expanded business benefits afforded by maximum Bluetooth density.

Plantronics has long been rooted at the forefront of audio device technology. The next-generation Bluetooth density simulations provided in this paper underscore our continued commitment to evolving the knowledge base for density planning, with our partners and customers.

Other factors besides density are involved with deploying high volumes of Bluetooth headsets, such as floor thickness and Bluetooth classes of device. We will be testing and publishing future guidance on our findings.

For more information visit www.plantronics.com or (800) 544-4660, extension 5521.

APPENDIX A: ADDITIONAL ANALYSIS MATERIALS

Tables 1 and 2 below provide specific reference to the graphic plots in Simulation 1, Graph 1, in square meters and square feet. Shown is the area required to avoid density-related interference given the number of users, and the coexistence of zero, one, or two Wi-Fi APs within the given environment. All area figures assume worst-case call traffic loading at a maximum of 100% (1.00 Erlang, 36.00 CCS).

Table 1: Density values for Bluetooth deployment reference, in **square meters** per user or Bluetooth headset base; call traffic loading at 100%

# OF USERS	NO APS AREA REQ'D	ONE AP AREA REQ'D	TWO APS AREA REQ'D
25	0.3	1.7	17.6
49	1.7	5.8	25.0
81	3.6	7.8	30.3
100	4.8	9.6	32.5
144	6.3	11.6	34.8
225	7.3	13.0	36.0

Table 2: Density values for Bluetooth deployment reference, in **square feet** per user or Bluetooth headset base; call traffic loading at 100%

# OF USERS	NO APS AREA REQ'D	ONE AP AREA REQ'D	TWO APS AREA REQ'D
25	2.7	18.2	189.9
49	18.2	62.0	269.1
81	38.9	84.4	325.6
100	52.1	103.4	349.7
144	67.3	124.4	374.7
225	78.5	139.5	387.5

Tables 3 and 4 below provide the minimum spacing required between base systems in meters and feet, to achieve the density recommendations in Tables 1 and 2.

Table 3: Minimum Bluetooth headset base spacing requirements in **meters**; call traffic loading at 100%

# OF USERS	NO AP SPACING	ONE AP SPACING	TWO APS AREA REQ'D
25	0.5	1.3	4.2
49	1.3	2.4	5.0
81	1.9	2.8	5.5
100	2.2	3.1	5.7
144	2.5	3.4	5.9
225	2.7	3.6	6.0

Table 4: Minimum Bluetooth headset base spacing requirements in **feet**; call traffic loading at 100%

# OF USERS	NO AP SPACING	ONE AP SPACING	TWO APS AREA REQ'D
25	1.6	4.3	13.8
49	4.3	7.9	16.4
81	6.2	9.2	18.0
100	7.2	10.2	18.7
144	8.2	11.2	19.4
225	8.9	11.8	19.7

Tables 5 and 6 below provide specific reference to the graphic plots in Simulation 2, Graph 3, in square meters and square feet. Shown is the area required to avoid density-related interference given the number of users and the coexistence of zero, one, or two Wi-Fi Access Points within the given environment. All area figures assume call traffic loading at 50%.

Table 5: Density values for Bluetooth deployment reference, in **square meters** per user or Bluetooth headset base; call traffic loading at 50%

# OF USERS	NO APS AREA REQ'D	ONE AP AREA REQ'D	TWO APS AREA REQ'D
25	0.0	0.0	3.2
49	0.0	0.5	7.8
81	0.5	2.0	9.9
100	0.6	2.4	10.6
144	1.2	3.1	12.3
225	2.0	4.0	14.1

Table 6: Density values for Bluetooth deployment reference, in **square feet** per user or Bluetooth headset base; call traffic loading at 50%

# OF USERS	NO APS AREA REQ'D	ONE AP AREA REQ'D	TWO APS AREA REQ'D
25	0.0	0.0	34.9
49	0.0	5.3	84.4
81	5.3	21.1	106.8
100	6.9	25.9	113.7
144	13.0	33.0	131.9
225	21.1	43.1	151.4

Tables 7 and 8 below provide the minimum spacing required between headset bases in meters and feet, to achieve the density recommendations in Tables 5 and 6.

Table 7: Minimum Bluetooth headset base spacing requirements in **meters**; call traffic loading at 50%

# OF USERS	NO AP SPACING	ONE AP SPACING	TWO APS AREA REQ'D
25	0.0	0.0	1.8
49	0.0	0.7	2.8
81	0.7	1.4	3.2
100	0.8	1.6	3.3
144	1.1	1.8	3.5
225	1.4	2.0	3.8

Table 8: Minimum Bluetooth headset base spacing requirements in **feet**; call traffic loading at 50%

# OF USERS	NO AP SPACING	ONE AP SPACING	TWO APS AREA REQ'D
25	0.0	0.0	5.9
49	0.0	2.3	9.2
81	2.3	4.6	10.3
100	2.6	5.1	10.7
144	3.6	5.7	11.5
225	4.6	6.6	12.3

Tables 9 and 10 below provide specific reference to the graphic plots in Simulation 3, Graph 5, in square meters and square feet. Shown is the area required to avoid density-related interference given the number of users and the coexistence of zero, one, or two Wi-Fi APs within the environment. All area figures assume a constant 10 x 10 grid of 100 users.

Table 9: Variable call fraffic loading impact on Bluetooth density in **square meters** per user; 10x10 grid, 100 users

MINUTES ON PHONE/HOUR	CALL TRAFFIC IN CCS	CALL TRAFFIC IN ERLANGS	*NO APS AREA*	*ONE AP AREA*	*TWO APS AREA*
6.0	3.6	0.10	-	-	-
12.0	7.2	0.20	-	-	1.4
19.8	11.9	0.33	-	-	5.1
30.0	18.0	0.50	-	2.3	10.2
40.2	24.1	0.67	1.7	4.4	17.6
51.0	30.6	0.85	3.2	7.0	25.0
60.0	36.0	1.00	4.6	9.3	31.9

Table 10: Variable call fraffic loading impact on Bluetooth density in **square feet** per user; 10x10 grid, 100 users

MINUTES ON PHONE/HOUR	CALL TRAFFIC IN CCS	CALL TRAFFIC IN ERLANGS	*NO APS AREA*	*ONE AP AREA*	*TWO APS AREA*
6.0	3.6	0.10	-	-	-
12.0	7.2	0.20	-	-	15.5
19.8	11.9	0.33	-	-	54.5
30.0	18.0	0.50	-	24.2	110.2
40.2	24.1	0.67	18.2	47.5	189.9
51.0	30.6	0.85	34.9	75.6	269.1
60.0	36.0	1.00	49.8	100.1	343.6

Tables 11 and 12 below provide the minimum spacing required between headset bases in meters and feet, to achieve the density recommendations in Tables 9 and 10.

Note: Because the maximum loading for a random shared medium is approximately equal to 30% (~30%), such as with Ethernet hub architecture, the tables here highlight this percentage for reference purposes.

Table 11: Variable call fraffic loading impact on Bluetooth base space density in **meters** per user; 10x10 grid, 100 users

MINUTES ON PHONE/HOUR	CALL TRAFFIC IN CCS	CALL TRAFFIC IN ERLANGS	*NO AP SPACING*	*ONE AP SPACING*	*TWO APS SPACING*
6.0	3.6	0.10	-	-	-
12.0	7.2	0.20	-	-	1.2
19.8	11.9	0.33	-	-	2.3
30.0	18.0	0.50	-	1.5	3.2
40.2	24.1	0.67	1.3	2.1	4.2
51.0	30.6	0.85	1.8	2.7	5.0
60.0	36.0	1.00	2.15	3.1	5.7

Table 12: Variable call fraffic loading impact on Bluetooth base space density in **feet** per user; 10x10 grid, 100 users

MINUTES ON PHONE/HOUR	CALL TRAFFIC IN CCS	CALL TRAFFIC IN ERLANGS	*NO AP SPACING*	*ONE AP SPACING*	*TWO APS SPACING*
6.0	3.6	0.10	-	-	-
12.0	7.2	0.20	-	-	3.9
19.8	11.9	0.33	-	-	7.4
30.0	18.0	0.50	-	4.9	10.5
40.2	24.1	0.67	4.3	6.9	13.8
51.0	30.6	0.85	5.9	8.7	16.4
60.0	36.0	1.00	7.1	10.0	18.5

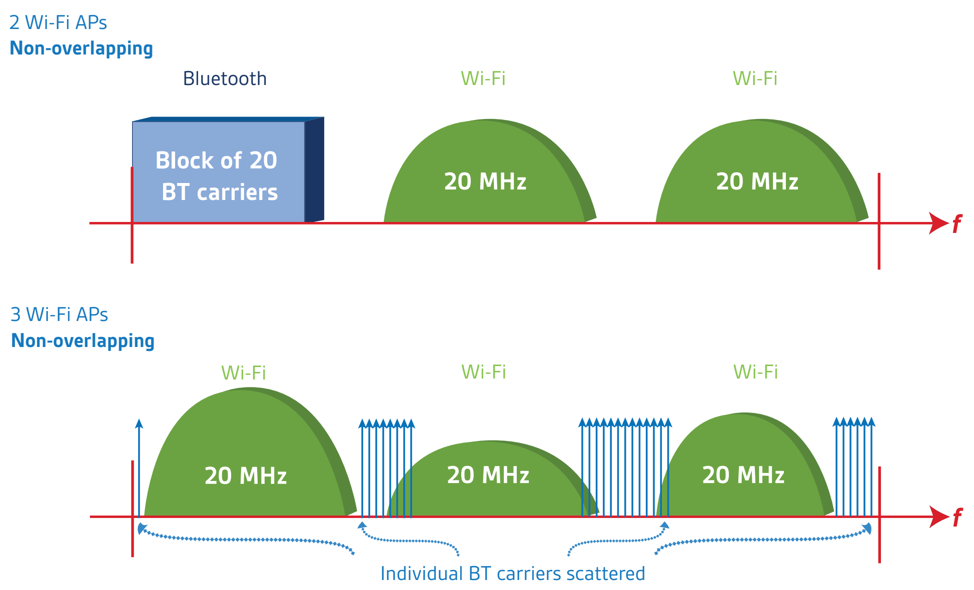
APPENDIX B:
ADDITIONAL FACTORS TO CONSIDER FOR BLUETOOTH PLANNING

This appendix furnishes important supplementary information for Bluetooth planning efforts by IT organizations, by addressing relevant questions one might ask when performing Bluetooth density analysis.

Q: What is the impact of three Wi-Fi APs on Bluetooth Density if all three APs are on non-overlapping channels? Note: 802.11 b/g/n all utilize both overlapping and non-overlapping channels.

A: Three Wi-Fi APs using non-overlapping channels will pose a challenge for Bluetooth device deployment because theoretically there is no spectrum left for additional radio systems. However, Bluetooth will scan the spectrum and will use the part with the least amount of activity/power, or more specifically, reuse the spectrum of the AP farthest away. At a minimum, Bluetooth will select 20 carriers, which do not need to be sequential so they may fit between the segments occupied by the APs as shown in the example below. Bluetooth will use the remaining spectrum available to the best of its abilities, but error rates may increase to above 1% FER.

Figure 2: Wi-Fi APs on Bluetooth Density with all 3 APs on non-overlapping channels

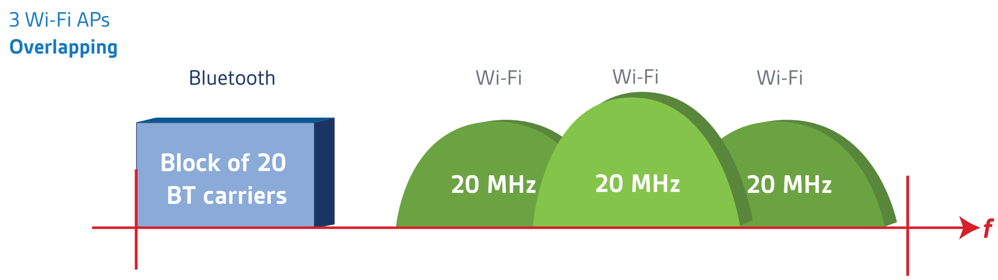


**NOTE: 802.11 b/g/n all utilize both overlapping and non-overlapping channels.*

Q: What is the impact of three Wi-Fi APs on Bluetooth density if the APs are on overlapping channels?

A: If the channels do overlap, additional free spectrum is accessible for Bluetooth and better results can be achieved because the spectrum occupied by three overlapping Wi-Fi channels may be as wide as with two non-overlapping channels. In this case, the Bluetooth density results would be identical as in the case with two non-overlapping Wi-Fi channels.

Figure 3: Impact of three Wi-Fi APs on Bluetooth Density if the APs are on overlapping channels



Q: What is the impact on Bluetooth density for users streaming A2DP (streaming stereo Bluetooth audio) within the office environment?

A: A2DP is a Bluetooth specification for streaming music or media downlink to the headset. In terms of capacity, streaming music or media over an A2DP link requires 350kb/s (asymmetrically). This equals 2.5 x more spectrum than voice communications, which use 64kb/s in both uplink and downlink.

Q: What is the impact of non-communications Bluetooth devices, such as Bluetooth mice and keyboards, on Bluetooth density?

A: The load on a mouse or keyboard Bluetooth channel is very low relative to communications devices and not is considered a significant factor in density planning for communications headsets.

Q: How could the introduction of Bluetooth Class 1 or pseudo Class 1 devices into the office environment affect density planning?

A: Bluetooth headsets with class 1 power and dynamic power control provide greater operating range while avoiding the interference problems typically associated with class 1 operation. When the headset is close to the Bluetooth source, the headset will operate at class 2 levels, reducing range and minimizing the risk of interference. When greater range is needed the headset will automatically switch to class 1 operation to support the increased distance.