How to Design a High-Density Network

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Where can we find high density networks?

Definitions:
a high-density wireless network provides pervasive connectivity for all devices within a defined space
capacity is the number of clients served by a single AP; and the data throughput required for the client application

Approximations to show relative client density and throughput. Some use cases can exceed what is shown

Warehouse Logistics  
~ 256kbps to 1Mbps per device

Enterprise / Retail  
~ .75 to 10Mbps per device

K12 EDU  
20-40

Education  
~ 1 to 20Mbps per device

Higher ED  
40-60

Event CTR  
30-80

Stadiums  
160

IOT, Ultra-High Density Mobile devices

Number of Clients per 100sqm (~1000 sqft)
Approximate Req Bandwidth Per Client based on typical applications

Off the scale
Characteristics of a well operating high-density network:

1. Low packet retransmissions rate
2. Low packet latency and jitter (1-2ms)
3. Balanced uplink / downlink datarates within the cell

Three keys to consider with a high-density network:

1. Throughput required to meet the application(s)
2. Survey and design for high SNR
3. Configure the APs for high density

I've heard Wi-Fi 6 was 'high efficiency'. Is it 'high density' or 'high efficiency'?
# Know the applications that clients will use

<table>
<thead>
<tr>
<th>Application</th>
<th>Bitrate</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streaming Video</td>
<td>750kbps – 15Mbps</td>
<td>K12 online applications use low bitrate video window, higher education may use 4k full screen</td>
</tr>
<tr>
<td>Video Conferencing</td>
<td>750kbps – 2Mbps</td>
<td>Default video mode is 360p 12-25fps. Quality can be set up to 720p and higher frame rate</td>
</tr>
<tr>
<td>General Web Browsing</td>
<td>500kbps avg</td>
<td>Web browsing is bursty, low average bitrate, highly multiplexed due to browsing behaviour</td>
</tr>
<tr>
<td>Voice calls</td>
<td>96kbps</td>
<td>For common voice codecs</td>
</tr>
</tbody>
</table>

**Tip:**

All network traffic is multiplexed, so you cannot use simple math. Must account for bursty traffic patterns and usage patterns.

TTL BW does not = Application BW * Number of Client
Typical AP is 6x more powerful than typical smart phone

Client at the edge of range
AP transmits more signal
Client can receive packets, but cannot respond to the AP
Result:
• Dropped connections
• Excessive client roaming
• Consume the battery
• Bad experience 😞

Strong downlink RF signal
Weak uplink signal creates a bad experience

-60dBm
-70dBm
-80dBm
Design for Capacity

Client within range

Reduce cell size by:

- Reduce AP transmit power
- Disable 802.11bg
- Prune low datarates

Expected Results:

- Lower packet latency
- Lower packet retry rate
- Consist rates across cells
- Higher capacity and density
RF propagation

Inverse Square Law

signal level will be reduced by a factor that is inversely proportional to the square of the distance from the source.

What that means

The signal measured at distance $2r$ will be $1/4$th the signal at $r$, and the signal measured at $3r$ will be $1/9$th the signal at $r$. 

\[
\begin{align*}
\text{at } r & : 1 \\
\text{at } 2r & : \frac{1}{4} \\
\text{at } 3r & : \frac{1}{9}
\end{align*}
\]
Impact on roaming through wireless cells

**Connection imbalance between wireless cells**

- Dropped connections
- Excessive client roaming scans
- High battery drain
Overlapping cells

**Balanced datarates, 30% overlap between cells**

- Consistent roaming between cells
- Low packet latency
- Good experience
Configure the AP for high density design

802.11 b g n a ac ax

Designed for coverage
Configure the AP for high density design

802.11 n ac ax

2.4GHz best for IOT devices, and coverage holes

Designed for capacity
Configure the AP for high density design

- Two frequency bands used in 802.11 Wi-Fi: 2.4GHz and 5GHz (for now)
- 2.4GHz has 3 non-overlapping channels: 1, 6, 11
  - Difficult to separate in dense environments
  - Shared with RF interfering sources e.g. cordless phone, Bluetooth, mifi devices, microwave
- 5GHz has 24 non-overlapping channels
Legacy Networks: Double 5GHz capacity for Education, Hospitality, Enterprise

Ideal for 11n, 11ac mixed with new 11ax devices

802.11ax: Migrate to 8x8 for full MU-OFDMA, MU-MIMO, IOT ready

Ideal for 11ac, mostly 11ax, IOT mixed networks
Using SDR to enable flexible deployments

- 2 AP’s Providing 6 total 5ghz radios and 2 in 2.4ghz
- Maximize Spectrum without turning off radios
- Lowest Total Cost of Ownership due to less AP’s, Cabling and Switch Port Costs
Using SDR to enable flexible deployments

- Right Size the design based on number of users and Application Importance
- No turning off fixed 2.4ghz radios
- Dedicate radios for your faster clients
Using SDR to enable flexible deployments

SDR live demo

Note

• Easily test with and without SDR
• No special firmware to load, it’s built in and ready
• Allows flexible deployments tailored to the client types, applications
## Summary of the network planning and configuration

<table>
<thead>
<tr>
<th>Task</th>
<th>Bitrate</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Planning</td>
<td>-60dBm RSSI, 30dB SNR</td>
<td>Higher SNR = higher rate, lower latency, but requires more careful AP installation and configuration to control CCI/ACI</td>
</tr>
<tr>
<td>Configuration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disable 802.11abg</td>
<td></td>
<td>These protocols party like it’s 1999… time to say goodbye</td>
</tr>
<tr>
<td>Prune rates &lt;24Mbps</td>
<td></td>
<td>Reduces the range of the wireless cell advertisements, reduces connections to far away clients</td>
</tr>
<tr>
<td>Enable 802.11kvr</td>
<td></td>
<td>Smart protocols that enable better resource management, roaming for improved client experience</td>
</tr>
<tr>
<td>Enable Automatic RF management</td>
<td></td>
<td>Wireless vendor specific optimizations to mitigate interference, assist with roaming, and select optimal power and channel</td>
</tr>
</tbody>
</table>
Thank you