Advantages of Code Channelization

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Objectives of the Document

- Conventional idea: Code Channelization of the direct sequence system is not useful because of:
  - Near-Far problem
  - No enough separation
  - Complexity of the CDMA system

- This document is an introduction to overcome conventional ideas of the channelization and to prove usefulness of Code Channelization.
**Requirement of more frequency channels causes:**

- Less robustness against multipath because of narrower spreading bandwidth
- Less sensitivity because of more bits/symbol
- Sometimes amplitude component of the signal, because of more bits/symbol, to consume more power than flat envelope.

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**Aspect of the BSA**

Reliable BSA area in which acceptable throughput can be guaranteed always and everywhere.

Unreliable BSA area in which the throughput becomes unacceptable depending on time and place.

*MIS tries to build WLAN using reliable BSA area.*
**Three freq. channels are enough?**

This figure shows conceptual BSA arrangement using three frequency channels.

Reliable BSA areas are well separated by frequency channels but unreliable BSA areas overlap reliable BSA areas to cause degradation of performance.

**Undesirable neighbors**

SOHO is a very attractive market for WLAN.

It requires many channels in order to avoid interference from neighbors’ WLAN systems.

Management is not available against neighbors.
Micrilor’s channelization proposal

- Two frequency channels are available within 2400 - 2483.5 MHz ISM band.
- Eight search-code channels are also available independently to frequency channels.
- **Sixteen total channels** are available by combination of frequency channels and code channels.
- Forty-eight data-code channels are also available.

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An example of BSA arrangement by using 16 channels

(f1,C1) (f2,C1) (f1,C2) (f2,C2) (f1,C1)
(f2,C3) (f1,C3) (f2,C4) (f1,C4) (f2,C3)
(f1,C5) (f2,C5) (f1,C6) (f2,C6) (f1,C5)
(f2,C7) (f1,C7) (f2,C8) (f1,C8) (f2,C7)
(f1,C1) (f2,C1) (f1,C2) (f2,C2) (f1,C1)

Four reliable-BSA distance

Four reliable-BSA distance
Simulation

- Throughput for two adjacent BSAs with:
  - The same frequency channel and different code channels.
  - Same frequency channel and code channel.
- Throughput and delay time under interferences from neighbors’ systems.
- Using BONEs DESIGNER ver.3.6 by ALTA GROUP of Cedence Design systems, Inc.

Conditions (1)

1. The channel access model is based on 802.11 (P802.11D6.1 pp 86-pp 98).
2. DATA type is INF_DATA and ACK only.
3. The INF_DATA packets are generated by Poisson distribution.
4. The radio propagation characteristic is ideal, namely Frame Error is caused by collisions only.
5. No hidden node is considered.
6. INF packets consist of same information with fixed length.
7. Header length not considered.
8. The positions of STAs are fixed.
9. Data flow direction: AP to STAs (config. 1 and 2) STAs to AP (config. 3)
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### Conditions (2)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propagation Delay [msec]</td>
<td>0.0001 (0.1 [ms])</td>
</tr>
<tr>
<td>ACK Length [bits]</td>
<td>112 (=14 [bytes])</td>
</tr>
<tr>
<td>Transmit Speed [bps]</td>
<td>10M</td>
</tr>
<tr>
<td>Cwmin</td>
<td>32</td>
</tr>
<tr>
<td>Retransmission</td>
<td>3</td>
</tr>
<tr>
<td>Rx-Tx Delay [msec]</td>
<td>0.015</td>
</tr>
<tr>
<td>Mean Inter-Pulse Time [msec]</td>
<td>INF Length * Nodes / Transmit Speed / Load</td>
</tr>
<tr>
<td>Slot Time [msec]</td>
<td>Propagation Delay + Rx-Tx Delay</td>
</tr>
<tr>
<td>SIFS [msec]</td>
<td>Rx-Tx Delay</td>
</tr>
<tr>
<td>DIFS [msec]</td>
<td>SIFS + 2 * Slot Time</td>
</tr>
<tr>
<td>Timeout Time</td>
<td>3 * Propagation Delay + Rx-Tx Delay + SIFS + (INF Length + ACK Length) / Transmit Speed</td>
</tr>
</tbody>
</table>

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### System Configuration - 1

- : An AP belongs to BSA-1
- : An AP belongs to BSA-2
- : Stations belongs to BSA-1
- : Stations belongs to BSA-2
**Throughput under config. -1**
(INF Length = 4000 bit)

D/U is a parameter of the radio, just the same as -Mj(dB) which is jamming margin.

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**Jamming margin (Mj) of JX-4000F**

Average Mj ~ -2.5dB

Baseband Modulation : 16 bit Bi-Orthogonal keying * 16 chips PN sequence
Carrier Modulation : BPSK
Decision Threshold : BER < 10^{-5}
Type of Jammer : CW

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Throughput under config. -1
(INF Length = 12000 bit)

Solid fine line: Same freq. and code Ch.
Solid thick line: Different freq. channels
Dashed line: Same freq. Ch. and Different code channels

Probability of Packet Success under config. -1
(Z_0 = -5dB)

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Probability of Packet Success under config. -1
$(Z_0 = 0\text{dB})$

```
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2

Load
```

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Probability of Packet Success under config. -1
$(Z_0 = 5\text{dB})$

```
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2

Load
```

---

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**System Configuration - 2**

- AP1, STA1-1, STA1-2, STA1-3, STA1-4
- BSA-1
- STA2-1, STA2-2, STA2-3, STA2-4
- BSA-2

- **■**: An AP belongs to BSA-1
- **□**: Stations belong to BSA-1
- **○**: An AP belongs to BSA-2
- **●**: Stations belong to BSA-2

**Throughput under config. -2**

*INF Length = 4000 bit*

![Graph showing throughput under different load conditions with various Zo dB levels.]

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Page 10
Probability of Packet Success under config.-2
(INF Length = 4000 bit, $Z_0 = -1$dB)

![Graph showing the probability of packet success under different configurations.](image)

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Probability of Packet Success under config.-2
(INF Length = 4000 bit, $Z_0 = 0$dB)

![Graph showing the probability of packet success under different configurations.](image)

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**Probability of Packet Success under config. -2**  
(INF Length = 4000 bit, $Z_0 = 1dB$)

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**Probability of Packet Success under config. -2**  
(INF Length = 4000 bit, $Z_0 = 2dB$)

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**Probability of Packet Success under config. -2**
*(INF Length = 4000 bit, \( Z_0 = 5 \text{dB} \))*

<table>
<thead>
<tr>
<th>Load</th>
<th>STA1-1</th>
<th>STA1-2</th>
<th>STA1-3</th>
<th>STA1-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>0.1</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
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</tr>
<tr>
<td>0.2</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>0.3</td>
<td>0.7</td>
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<tr>
<td>0.4</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
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</tr>
<tr>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>0.6</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
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<tr>
<td>0.7</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
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<tr>
<td>0.8</td>
<td>0.2</td>
<td>0.2</td>
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<tr>
<td>0.9</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*Solid line: Same freq. and code channels*
*Dashed line: Same freq. Ch. and Different code channels*

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**Prominent applications of code channelization**

- **Code Channelization** is useful especially in order to obtain *floor-to-floor isolation* or *room-to-room isolation*.
- The effectiveness has been proved through many applications of Clarion’s SS products in Japan.

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System Configuration - 3

My system and neighbors’ systems are being operated by the same frequency channel without code channelization. Signals from neighbors’ systems can be sensed by probability of $p$. D/U ratio is always enough large to ignore errors by collisions.

Maximum throughput under config. -3
(INF Length = 512bit)

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Maximum throughput under config. -3
(INF Length = 12000bit)

Load vs. Throughput under config. -3
INF Length = 512 bit, T_other = 0.01msec
(Aggregate Load of interference = 5.12)
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Load vs. Throughput under config. -3
INF Length = 512 bit, T_other = 0.1msec
(Aggregate Load of interferences = 0.512)

![Graph showing load vs. throughput for INF Length = 512 bit, T_other = 0.1msec.]

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Load vs. Throughput under config. -3
INF Length = 12000 bit, T_other = 0.1msec
(Aggregate Load of interferences = 0.512)

![Graph showing load vs. throughput for INF Length = 12000 bit, T_other = 0.1msec.]
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Doc.: IEEE P802.11-98/118

Load vs. Throughput under config. -3
INF Length = 512 bit, $T_{\text{other}} = 1\text{msec}$
(Aggregate Load of interferences = 0.0512)

![Graph 1]

Load vs. Throughput under config. -3
INF Length = 12000 bit, $T_{\text{other}} = 1\text{msec}$
(Aggregate Load of interferences = 0.0512)

![Graph 2]
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**Mean Delay under config. -3**

INF Length = 512, T_other = 0.1msec
(Aggregate Load of interferences = 0.512)

Load vs Delay

![Graph showing mean delay under different conditions](image)

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**Mean Delay under config. -3**

INF Length = 12000, T_other = 0.1msec
(Aggregate Load of interferences = 0.512)

Load vs Delay

![Graph showing mean delay under different conditions](image)
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**Mean Delay under config. -3**

INF Length = 512, $T_{other} = 1\text{msec}$

(Aggregate Load of interferences = 0.0512)

---

![Graph showing mean delay under different configurations](image)

- **Load vs Dealy**
- **Mean Delay (msec)**
- **Load**
- **p=1**
- **p=0.5**
- **p=0.25**
- **p=0.1**
- **p=0**

---

**Mean Delay under config. -3**

INF Length = 12000, $T_{other} = 1\text{msec}$

(Aggregate Load of interferences = 0.0512)

---

![Graph showing mean delay under different configurations](image)

- **Adjacent : Packet Period = 1\text{msec} 512bit/packet**
- **My BSA : 12000bit/packet**

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Conclusion

- Code channelization provides better throughput if BSAs are not overlapped.
  - To obtain floor-to-floor and room-to-room isolation.
  - For unmanaged BSAs (SOHO market).
- Substantial overlapping of BSAs causes degradation because of the Near-Far problem.
- Next simulation must show system capacity and include interference and leakage (shared capacity) effects.