Voice over Wireless LAN
Outline

- Introduction to VoWLAN
- Wireless LAN Technology
- Why VoWLAN?
- VoWLAN Requirement
- VoWLAN Challenge
- Summary
VoWLAN or Voice over Wireless Local Area Network expands the capability of WLANs or Wireless LANs.

VoWLAN is a natural extension of VoIP.

VoWLAN is the added feature that will enable you to make phone calls using this mobile Internet access.
VoWLAN Technology

- VoIP + Wireless LAN
- VoIP
  - SIP, RTP, H.323
- Wireless LAN
  - WiFi : 802.11a/b/g
  - WiMAX : 802.16
802.11 Overview

- Infrastructure mode

Wired Network

Access Point

End Device

Access Point

End Device

Access Point

End Device

End Device
802.11 Overview

- adhoc mode

Diagram showing End Devices connected in an ad hoc network.
802.11 Overview

- DCF: Distributed Coordination Function
- Contention-based MAC function

Diagram:
- DIFS
- Station A: Frame, CWindow
- Station B: Defer, Backoff, Frame
- Station C: Defer, Frame, CWindow
- Station D: Defer, Frame, CWindow
- Station E: Defer, Frame

CWindow = Contention Window
- = Backoff
- = Remaining Backoff
802.11 Overview

- PCF: Point Coordination Function
- Contention-free MAC function
# 802.11 Overview

<table>
<thead>
<tr>
<th></th>
<th>802.11b</th>
<th>802.11a</th>
<th>802.11g</th>
<th>802.11b +</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raw Data Rates</strong></td>
<td>11Mbps</td>
<td>54Mbps</td>
<td>54Mbps</td>
<td>22/44Mbps</td>
</tr>
<tr>
<td><strong>Average Actual throughput</strong></td>
<td>4~5Mbps</td>
<td>27Mbps</td>
<td>20~25Mbps</td>
<td>6 Mbps</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>2.4GHz</td>
<td>5GHz</td>
<td>2.4GHz</td>
<td>2.4GHz</td>
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<tr>
<td><strong>Available Spectrum</strong></td>
<td>83.5MHz</td>
<td>300MHz</td>
<td>83.5MHz</td>
<td>83.5MHz</td>
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<tr>
<td><strong>Modulation Encoding</strong></td>
<td>DSSS/CCK</td>
<td>OFDM</td>
<td>OFDM</td>
<td>PBCC</td>
</tr>
<tr>
<td><strong>Channels/ non-overlapping</strong></td>
<td>11/3</td>
<td>12/8</td>
<td>11/3</td>
<td>11/3</td>
</tr>
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</table>
## WiFi Phone protocol stack

<table>
<thead>
<tr>
<th>Control Plane</th>
<th>Data Plane</th>
<th>Management Plane</th>
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</thead>
<tbody>
<tr>
<td>SIP/SDP</td>
<td>RTP/RTC</td>
<td>RADIUS/DIAMETER</td>
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<table>
<thead>
<tr>
<th>Application</th>
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<tbody>
<tr>
<td>Vol P Application</td>
</tr>
<tr>
<td>Vocoder</td>
</tr>
<tr>
<td>MMI</td>
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</table>

<table>
<thead>
<tr>
<th>Layer</th>
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<tbody>
<tr>
<td>UDP/TCP</td>
</tr>
<tr>
<td>EAP/802.1x/...</td>
</tr>
<tr>
<td>IP</td>
</tr>
<tr>
<td>802.11e/f/h/i/k...</td>
</tr>
<tr>
<td>802.11 MAC</td>
</tr>
<tr>
<td>802.11 a/b/g/ RF/BB</td>
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</tbody>
</table>
Why VoWLAN

- Low cost
  - Free Charge of ISM Band
    - ISM band: free (2.4-2.4835 GHz)
    - 3G band: NTD 10 Billion
  - Inexpensive network deployment
    - Reuse of existing network, easy to setup
    - Low cost of Access Point VS. High cost of Base Station
Why VoWLAN

- Low complexity
  - Centralized architecture in cellular network
    - PBX contains most intelligence of the network
    - Typically hard to maintain the proprietary system
  - Decentralized architecture in VoIP network
    - Intelligence are implemented in User Agent
    - Easy for maintenance
Why VoWLAN

- Low transmission power
  - Small coverage of the AP, small transmission power needed
  - GSM: 500mW ~ 2W
  - WLAN: < 100mW
- Easy for providing value-added service
  - Voice and data service is integrated into VoIP
  - Flexibility of SIP protocol
Why VoWLAN

- Market trend
  - VoWLAN market will reach $507 million (end user revenue) by 2007 (In Stat/MDR)
  - VoWLAN handset will grow by more than 89 percent annually until 2007 when there will be more than 653,000 (On world)
VoWLAN Requirement

- **Performance**
  - Voice quality must be as good as wired network
    - Delay >100 ms is typically sensible by human
    - Low latency: <50 ms latency is recommended
  - Reliable transmission over wireless channel
    - Low packet lost rate

- **User mobility management**
  - Support roaming between wireless network
VoWLAN Requirement

- Capacity management
  - Heavy traffic load increase packet lost rate and latency
  - Number of Users must be controlled

- Channel assignment
  - 11 channels in 802.11b
  - Manage operating channel among adjacent Access Point
VoWLAN Requirement

- Security
  - Data ciphering
    - Wireless channel is insecure
    - Data over wireless should be protected
  - AAA
    - Authentication: legal user identification
    - Authorization: service level differentiation
    - Accounting: statistics for billing

- Location Tracking
VoWLAN Challenge

- Due to the requirements of VoWLAN, several issue should be solved
- User Mobility Issue
- Power Consumption Issue
- Security Issue
- QoS Issue
- Capacity Issue
- Other Related Issue
User Mobility Issue

- Supporting user mobility is an important feature of VoWLAN
- Typically concern about two factors
  - Handoff latency
  - Packet lost rate
- Seamless handoff
  - Fast handover: focus on reducing handoff latency
  - Smooth handover: focus on reducing packet loss during handoff
Handoff Approach

Layer 2 approach

1: reassociation
2: auth (802.1x, EAP)
3: auth (RADIUS/DIAMETER)
4: packet send/recv
Handoff Approach

- MIP approach

HA FA

CN

Access Point

FA

Access Point

MN
Handoff Approach

- SIP Mobility approach
  - REINVITE

MN

SIP Proxy

Access Point

AAA Server

Access Point

MN
Handoff Approach

- Intra ESS
  - L2 approach with/without authentication
- Inter ESS
  - DHCP + MIP
  - DHCP + SIP Mobility
- Inter Domain
  - Same as Inter ESS, but business policy should be concerned
Power Consumption Issue

- Always be a problem since only limited battery power available at mobile device
- System
  - CPU, Memory, LCD, DSP/Codec
- WLAN
  - Physical Layer: RF
  - MAC Layer: 802.11a/b/g
  - Network Layer: TCP/IP
802.11 Power Saving Mode

- Reduce power consumption of transceiver when mobile device is idle
- AP buffers data packet for the mobile device which is in PSM, and inform it to receive by sending beacon
- Mobile device in PSM periodically wake up to receive data packet buffered in AP
802.11 Power Saving Mode

- **beacon**
- **beacon with data**
- **PS poll**
- **PS data**

**AP**

- Beacon Interval
- Wait Interval

**Client 1**
- Sleep

**Client 2**
- Sleep
802.11h

- Supplementary to 802.11a (5GHz)
- TPC (Transmission Power Control)
  - Keeps signal strength efficient, using only enough power to reach active users rather than using a uniform power output
- DFS (Dynamic Frequency Selection)
  - Selects the radio channel at the access point to minimize interference with other systems
Security Issue

- Data ciphering
  - WEP, 802.11i
- AAA (Authentication, Authorization, Accounting)
  - 802.1x, RADIUS, DIAMETER
WEP

- WEP uses RC4 to encrypt data which is dependent on the IV (Initialization Vector) and Shared Key.
802.11i

- Data transfer protection
  - TKIP: based on RC4
  - CCMP: import AES algorithm with better security
- Authentication
  - 802.1x, EAP
802.1x

- General-purpose, port-based network access control mechanism for any 802 technology
- Enables mutual authentication of devices
- Provides service for exchange of 802.11 session keys
- Leverages existing AAA infrastructure
- Extensible protocol to support future authentication methods (RFC 2284)
802.1x – EAP Authentication

- End Device
  - Request/Identity
  - Response/Identity
  - EAP-Request
  - EAP-Response
  - EAP-Success

- Access Point
  - Radius-Access-Request
  - Radius-Access-Challenge

- Auth Server
  - Radius-Access-Request
  - Radius-Access-Challenge

802.1X

RADIUS
QoS Issue

- Typically, voice quality is depend on the delay and loss rate of packets.
- No QoS guarantee in legacy 802.11 DCF, since each mobile device contends for the channel by using CSMA/CA.
- There are some proprietary QoS schemes proposed, but QoS is still an open issue.
802.11e

- Promise to bring QoS capabilities WLAN system need for streaming applications
- Introduce HCF (Hybrid Coordination Function) to provide some QoS facilities
  - EDCA : Enhanced Distributed Cannel Access
  - HCCA : Hybrid coordination function Controlled Channel Access
EDCA

- Contention-based channel access
- Four backoff entities within one station
- Each backoff entity represents one Access Category (AC) and has different contention window size
  - AC_VO (voice), AC_VI (video), AC_BE (best effort), AC_BK (background)
HCCA

- Controlled channel access
- HC can allocate TXOP (Transmission Opportunity) during CFP or CP by transmitting QoS CF-Poll frame
- During CFP, this mechanism is the same as legacy 802.11
- During CP, it will allocate the medium after detecting the channel being idle for PIFS
802.11e Superframe

Contention Free Period

Contestation Period

Polled TXOP

TXOP

Polled TXOP
Capacity Issue

- Voice quality is a key component of voice service (real-time, high throughput)
- CSMA/CA mechanism limits the max # of subscribers under the AP
  - A VoIP stream typically requires less than 10Kbps
  - Ideally, the number of simultaneously VoWLAN sessions is
    - $11M / (10K * 2) = 550$
  - However, the maximum number of VoIP sessions is about 12 if GSM 6.10 (13.2Kbps) is used
Capacity Issue

- An analysis result from “W. Wang et al, Solution to Performance Problems in VoIP over 802.11 Wireless LAN”

<table>
<thead>
<tr>
<th>Codec</th>
<th>Max # of user</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM 6.10</td>
<td>11.2</td>
</tr>
<tr>
<td>G.711</td>
<td>10.2</td>
</tr>
<tr>
<td>G.732.1</td>
<td>17.2</td>
</tr>
<tr>
<td>G.726-32</td>
<td>10.8</td>
</tr>
<tr>
<td>G.729</td>
<td>11.4</td>
</tr>
</tbody>
</table>
**Multiplex-Multicast Scheme**

- **Multiplex**: Combine several downlink data into one
- **Multicast**: Multicast the packet to all destination
- **De-Multiplex**: Retrieving the corresponding payload

![Diagram of Multiplex-Multicast Scheme](image-url)
Other Related Issue

- **Codec Compression**
  - The ability to maximize the wireless bandwidth for voice, intelligent use of compression codec is important.
  - Often require hardware assist, the target device is hardware dependent and needs to be specially designed

- **PBX Integration**
  - Provide the PSTN access, often a gateway solution
  - SIP ENUM
Other Related Issue

- Combine WLAN and Cellular
- WLAN
  - High bandwidth, Low Cost, Multimedia Service, Video Phone
- Cellular
  - Large Coverage, High Mobility, Mature Billing System, Popularity
Summary

- The existing VoWLAN solutions may not be robust and reliable enough to support deployment for a large base of users.
- QoS of VoWLAN is always an open issue:
  - it may or may not have a good solution.
- Security and Capabilities for fast handoff between APs still needs some improvement.
Summary

- RF management and MAC layer mechanism affect power consumption of mobile device
- Voice over WLAN is a trend
  - Many cellular operators have devoted to the development of VoWLAN
  - Government promotes the combination of WLAN and Cellular network
  - VoWLAN may just be the next big thing in mobile telephony