Wi-Fi enabled sensors for Internet of Things: a practical approach

Wi-Fi enabled sensors for Internet of Things: a practical approach

• How many keywords in the title?

• What is the main scenario?
  – Wi-Fi enabled Sensors or Internet of Things?

• What is the main method?
IoT and a challenge

• **IoT:** *everything is connected*

• **Challenge:** *various interfaces make it difficult to connect*
A solution: use same interface

Communication technology X

Communication Technology X

Communication Technology X

Question: What is technology X?
Traditional technology: Zigbee-based Sensor Networks

ZigBee Coordinator (FFD)
ZigBee End Device (RFD or FFD)

ZigBee network

FFD: full function devices
RFD: reduced function devices

ZigBee for home automation application
A new strong candidate: WiFi enabled devices

• Native IP connection
  – Big plus for IoT

• Cost savings
  – Reuse of existing WiFi infrastructure

• Years of battery lifetime
WiFi-enabled Sensors for Connected Home

Sensors access Internet
Is WiFi enabled sensors viable?

• Power consumption

• Reliability

• Communication range
POWER CONSUMPTION
Hardware

• Duty-cycle operation

[t_c: duty cycle period]
[t_w: wake-up period]
[t_s: Sleep state period]

• Sleep current
  – Turn off components that are not needed

• Wake-up energy
Communication energy

<table>
<thead>
<tr>
<th>Technology</th>
<th>Data rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE 802.15.4</td>
<td>250kb/s</td>
</tr>
<tr>
<td>IEEE 802.11b/g</td>
<td>1MB/s – 54MB/s</td>
</tr>
</tbody>
</table>

- Wifi-enabled sensors have higher data rate, and hence yields much lower energy per bit.
MAC retransmission

• MAC retransmission has significant impact for low data rate operation

sender

Packet sent, wait for acknowledgement (ACK)

Packet lost and re-sent, wait for ACK

Packet lost and re-sent, wait for ACK

Packet transmitted successfully

receiver
## Security & power consumption

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Security</th>
<th>Power consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEP</td>
<td>Weak</td>
<td>Low authentication time</td>
</tr>
<tr>
<td>WPA</td>
<td>strong</td>
<td>Considerable authentication time</td>
</tr>
<tr>
<td>WPA2/AES-PSK</td>
<td>Best tradeoff between security and performance</td>
<td></td>
</tr>
</tbody>
</table>
How to understand Fig. 3?

• Three keywords
  – Scenarios, packet size, data rate

• Three scenarios: the third scenario has the highest power consumption
Packet size effect (1/2)

8 bytes at 1Mbps

512 bytes at 1Mbps

Significant effect
Packet size effect (2/2)

8 bytes at 54 Mbps

512 bytes at 54 Mbps
High data rate decrease energy consumption

8 bytes at 1Mbps

8 bytes at 54Mbps
RELIABILITY
Operating frequency

• WiFi enabled sensors operate at 2.4GHz license-free frequency

• Many technologies operate at 2.4GHz
Two interference cases

In-network interference: Sensors and interferers are in the same Access Point (AP)

Out-of-network interference: Sensors and interferers are in different Access Point, but operate in the same channel
Performance Metrics for Reliability

- **Packet Successful Rate (PSR)**
  - 100 packets are sent out while 85 packets are successfully received; then, PSR = 85%

- **Round-trip-time (RTT)**
  - RTT = T2 - T1
How to understand Fig. 4?

• Three keywords
  – PSR, RTT, interference

- PSR
- RTT with different data rate
- RTT with different packet size
PSR observations

Question: right-side figure, why downlink has much lower PSR?

AP’s buffer fills up quickly and drop packets.
Main observations for RTT in Fig.4

- Cumulative distribution function (CDF): Probability that RTT is less than $x$:

$$F(x) = Pr(RTT < x)$$

96% RTT is less than 100ms
RANGE

Out of the range
Range Requirement

- Office environment, there are multiple APs throughout building
- Residential environment, a single AP covers the entire home
  - Question: Where to put the AP?
Main results in Fig.5 on home environment

• When AP is in basement
  – High data rate coverage for ground floor
  – Low data rate coverage for top floor

• When AP is in living room
  – Good coverage at 36-54Mbps at most location in both ground and top floor
  – Not good coverage in the basement
Conclusion

• The article demonstrated the feasibility in using WiFi-enabled sensors for IoT.

• Three points have been evaluated to demonstrate the feasibility
  – Power consumption
  – Impact of interference
  – Communication range
Exam: when and where?

- Room: room 2164 Delta
- Time: 10 December