Service Charge and Energy-Aware Vertical Handoff in Integrated IEEE 802.16e/802.11 Networks

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Outline

- Introduction
- System Model
- Scanning Rule for WLANS
- VHO Decision Framework
- Conclusion

Introduction

- Vertical handoff (VHO), i.e., handoff across heterogeneous access networks, is considered a key feature to bring the next generation wireless communication era.
- Three generalized steps of handoff：
  - Finding candidate networks
  - Deciding a handoff3
  - Executing a handoff

Introduction

- Comparison of VHO between WLAN and 3G system and VHO between WLAN and 802.16e.
- Two issues considered in this paper：
  - Finding a possible network
  - Making a decision

System Model

- Two assumptions：
  - The 802.16e network is assumed to be always reachable by MSTAs.
  - The 802.16e network can assist MSTAs to search available 802.11 networks.

Handling MSTA's Mobility-Related Issues

- The **velocity** of an MSTA is one of the important factors in VHO.
- The ping-pong effect.
- MSTA does not consider a VHO into WLANs when its speed exceeds a certain threshold V_{max}.

Handling MSTA's Mobility-Related Issues

- *Proposition 1:*

  V_{max} should satisfy the condition：

  Prob(s > kξ) > ϕ

$$v_{\max} = \frac{2r}{\kappa\zeta}\sqrt{1-\phi^2}$$

IEEE 802.16e-Assisted 802.11 Scanning

- How do MSTAs find 802.11 APs ?
- A simple method is that MSTAs should keep its WLAN interface turned on or switch it on periodically at a pre-determined time interval to detect a WLAN signal.
- Energy-efficient ?

IEEE 802.16e-Assisted 802.11 Scanning

- Which information will the 802.16e network provide to aid MSTAs to discovery available 802.11 APs ?
- The more detailed the information is, the more efficient scheme can be devised.
- Precious bandwidth resources.

IEEE 802.16e-Assisted 802.11 Scanning

- 1-octet overhead indicating the 802.11 AP density.
- Modify a MAC management message, called MOB_NBR-ADV.

TABLE I

MODIFIED MOB_NBR-ADV MESSAGE FORMAT.

Syntax	Size	Notes
Mgmt Message Type = 53	8 bits	
Optional fields bitmap	8 bits	Bit[0]= 1, omit Operator ID field ... **Bit[4]= 1, omit VHO fields** **Bit[5]-Bit[7]: reserved**
...	...	...
if(Bit[4]=0){		
VHO info	**8 bits**	**The 802.11 AP density in the 802.16e cell coverage**
}		
N_NEIGHBORS	8 bits	
...	...	...

Scanning Rule for WLANS

- *Proposition 2:*

  If $\rho > \rho_{min}$, an MSTA attempts to scan WLANs. Otherwise, turn off the WLAN interface until ρ is newly given by another 802.16e BS.

- *802.11 active scan & passive scan.*

802.11 Active Scan and Energy Consumption

- An active scan trial operates as follows:
  - After broadcasting a Probe Request frame at a specific frequency channel, if the channel stays idle for *min-ChannelTime*, declare the channel as empty.
  - If the channel becomes busy within in ChannelTime, waits for *maxChannelTime* in the receiving MAC state,and then handles Probe Response frames received afterwards.
  - Moving to the next channel, repeat the same procedures until there is no frequency channel to scan.

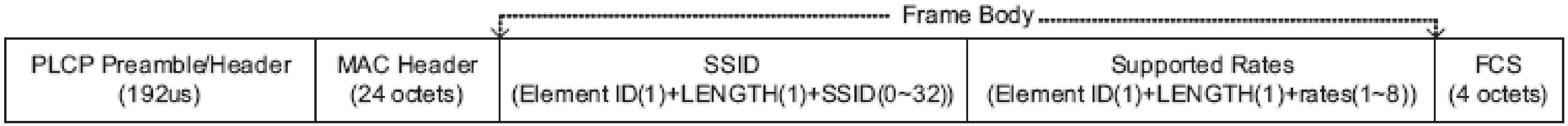
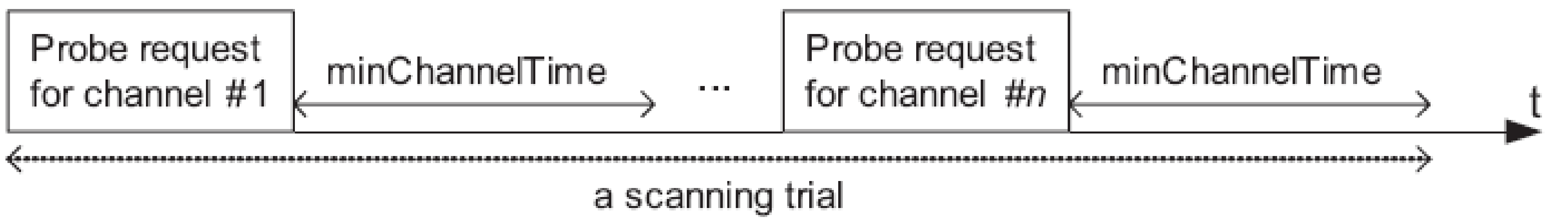
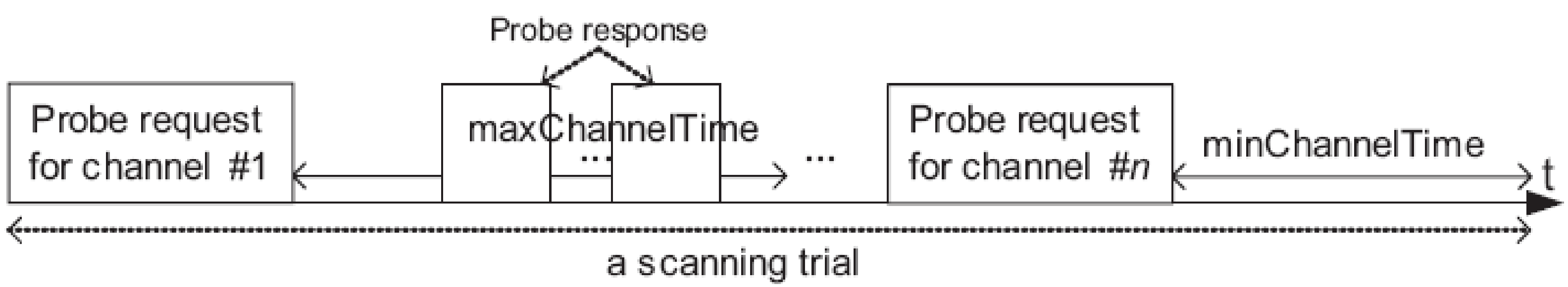


Fig. 1. Probe Request frame.



(a) The scan trial fails.



(b) The scan trial is successful.

Fig. 2. Transmissions of Probe Request frames during a scan trial.

802.11 Active Scan and Energy Consumption

- If a nonempty channel is examined, the scan time *Tu* is

$$T_u = T_{p\_req} + \mathrm{maxChannelTime}$$

- if an empty channel is examined, the scan time *Te* is

$$T_e = T_{p\_req} + \mathrm{minChannelTime}$$

802.11 Active Scan and Energy Consumption

- For total *n* frequency channels, each channel is sequentially examined by transmitting a Probe Request frame.
- A scan trial is completed if *n* sequential scans are completed.
- A scan trial is successful or failed.
- A scan interval $\tau_s >> nTe \simeq 23\ ms$ for $n = 11$ since $Te \simeq 2.12\ ms$

802.11 Active Scan and Energy Consumption

- *τ_s is lower-bounded by*

$$\tau_s \geq \tau_s^{\min} = 0.23 \ sec$$

- For τ_s, the energy consumption is minimized by changing MSTA’s MAC state to sleep or off state.

802.11 Active Scan and Energy Consumption

- A scan trial failed, the energy consumption is

$$\delta_{fail} = (DIFS + \frac{aCWmin}{2} + \mathrm{minChannelTime})P_l + (T_{p\_req} - DIFS - \frac{aCWmin}{2})P_t.$$

- Obviously,

$$\delta_{success} > \delta_{fail}$$

TABLE II

POWER CONSUMPTION DEPENDING ON THE MAC STATES OF WLAN [18].

MAC States	**Power Consumption**	Description
Off	$0\ mW$	Turns off the WLAN interface completely
Sleep	$P_s = 40\ mW$	Turns off most parts of circuit except for critical circuit
Listen	$P_l = 800\ mW$	Keeps sensing the carrier
Receive	$P_r = 900\ mW$	Performs the receive operations such as demodulation
Transmit	$P_t = 2,000\ mW$	Transmits the frame to the air

802.11 Active Scan and Energy Consumption

- $\mathcal{E}(k)$ ：the energy consumption after k scan trials.
- $\mathcal{E}_{fail}(k)$ is the lower bound of $\mathcal{E}(k)$,i.e. the energy consumption when all k trials failed.

$$\mathcal{E}_{fail}(k) = (n\delta_{fail} + \tau_s P_s)\, k$$

- When scanning is done during time t,

$$k = \left\lceil \frac{t}{nT_e + \tau_s} \right\rceil$$

802.11 Active Scan and Energy Consumption

- *Proposition 3:* *At a given time t, $\mathcal{E}_{fail}(k)$ is a decreasing function of τ_s.*

$$\frac{d\mathcal{E}_{fail}}{d\tau_s} = -\frac{nt}{(nT_e + \tau_s)^2}(\delta_{fail} - P_s T_e)$$

Analytical Model for Scanning in Mobile Environment

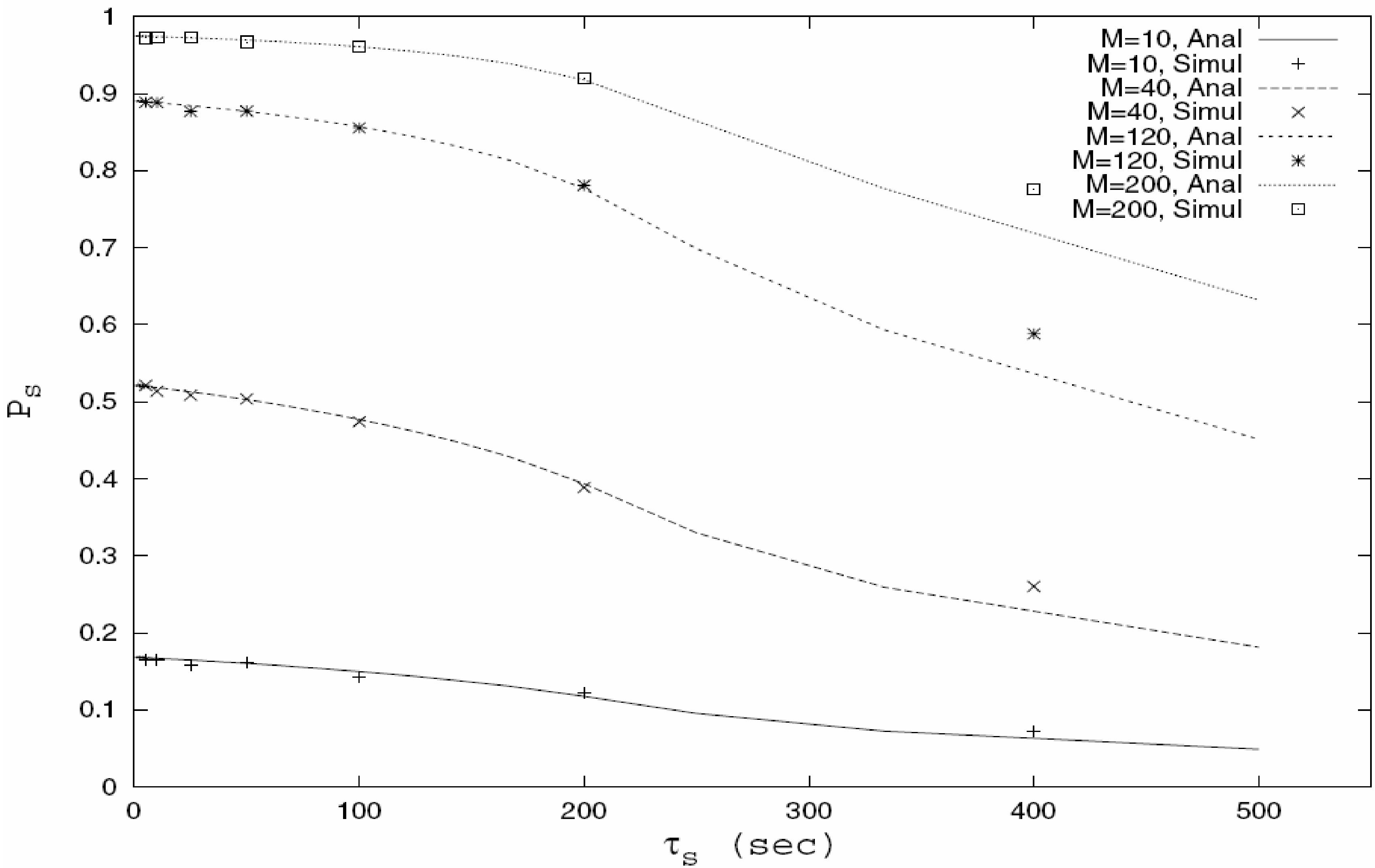
- $\triangle C(k)$ the additional area examined at the *k*-th scan trial.
- Letting $S(k) = \sum_{i=1}^{k} \Delta C(i)$
- the cumulative probability *Ps*(*k*) of a successful scan after *k* trials can be represented

$$P_s(k) = 1 - P(0) = 1 - e^{-\rho S(k)}$$

- Ps(k) is proportional to k.

Analytical Model for Scanning in Mobile Environment

- The profiles of the simulation：
  - The side of the square that is assumed to be the coverage of the 802.16e single-cell is $10^3\sqrt{\pi}$ m.
  - At time t = 0, and an MSTA are placed randomly in the square.
  - The MSTA starts to move according to the random waypoint model[19], and moves linearly with the constant speed.
  - A run of simulation is finished if the scan trial is successful or the simulation time reaches t_{max}.


M=10, Anal
M=10, Simul
M=40, Anal
M=40, Simul
M=120, Anal
M=120, Simul
M=200, Anal
M=200, Simul
P_S
τ_S (sec)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
100
200
300
400
500

Optimal Scanning Rule

- *Problem 1:* Scanning Problem in WLAN

$$\min \ \mathcal{E}_{fail}$$
$$s.t.$$
$$P_s \ \geq \ P_{target}$$

where the constraint is interpreted that the scan should succeed with a probability larger than P_{target}.

Optimal Scanning Rule

- *Proposition 4:* ρ_{min} *is the minimum* ρ*, which satisfies* $P_s \geqq P_{target}$ *using* $\tau_s = \tau_s^{\min}$
- For a given $\rho > \rho_{mn}$, we solve Problem 1 using the energy efficient scan policy (ESP) algorithm:

Energy-efficient Scan Policy (ESP)

- a small τ_s is preferred for a given *k* to minimize ε, *from k =* $\left\lceil \frac{t_{\max}}{nT_e + \tau_s} \right\rceil$

$$\tau_s = \max\left\{ \frac{t_{\max}}{k} - nT_e, \tau_s^{\min} \right\}$$

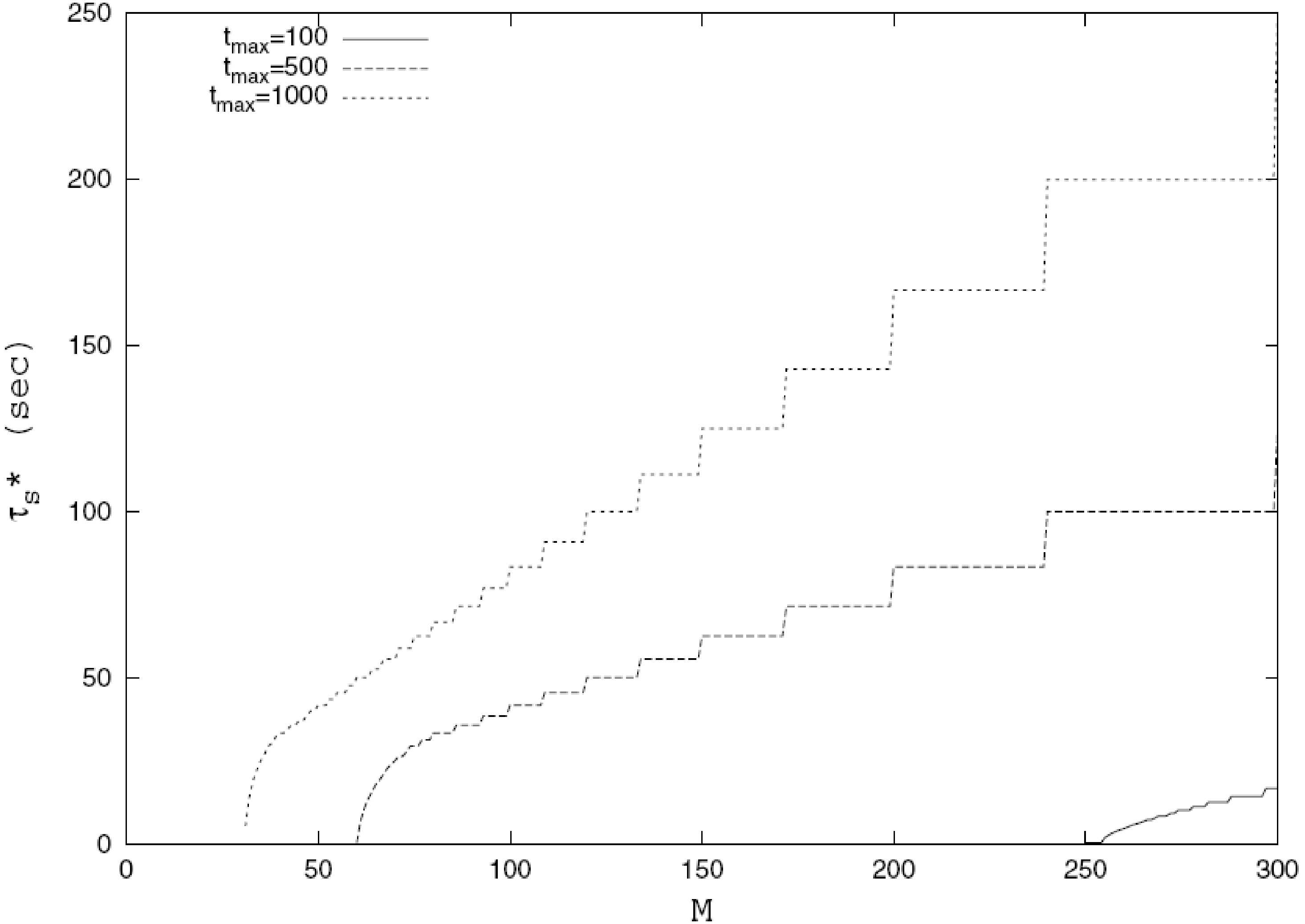
- According to Proposition 3, *k* should be minimized to maximize τ_s.

$$k_{\min} = \min\left\{ k \middle| S(k) \geq -\frac{\ln\left(1 - P_{target}\right)}{\rho} \right\}$$

Energy-efficient Scan Policy (ESP)

- Finally, the optimal scan interval τ^*_s is represented as

$$\tau_s^* = \max\left\{\frac{t_{\max}}{k_{\min}} - nT_e, \tau_s^{\min}\right\}$$



250
200
150
100
50
0
0
50
100
150
200
250
300
M
τs* (sec)
tmax=100
tmax=500
tmax=1000

VHO Decision Framework

- *Delayed Traffic Delivery (DTD)+ESP Algorithm*
- Periodic Scan (PS)
- DTD+PS

Conclusion

- 802.11 active scan, we develop a mathematical model, which shows the successful scan probability in terms of the AP density and the scan interval.
- Energy-efficient scan Policy (ESP) algorithm
- Under a practical service charge plan, it is beneficial for user to control the usage of the 802.16e network.