A Cross-Layer (Layer 2+3) Handoff Management Protocol for Next-Generation Wireless Systems

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Presented by Chun-Hung Liao

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- Mobility management in the NGWS
- Effect of layer 2 and layer 3 parameters on the performance of handoff management protocols
- Cross-Layer Handoff Management Protocol(CHMP)
- Performance evaluation of CHMP
- Conclusion

Introduction

- Next-generation wireless systems(NGWS) integrate different wireless networks to provide ubiquitous communication.
- It is an important and challenging issue to support seamless handoff management in NGWS.
- The existing handoff management protocols are not sufficient to guarantee handoff support.

Introduction

- In this work,a cross-layer(Layer 2+3) handoff management protocol,CHMP,is developed to support seamless handoff management in NGWS.

Mobility management in the NGWS

- Mobility management
  - Locatino management
  - Handoff management
    - Horizontal Handoff
      - Link-Layer Handoff
      - Intrasystem Handoff
    - Vertical Handoff(Intersystem Handoff)

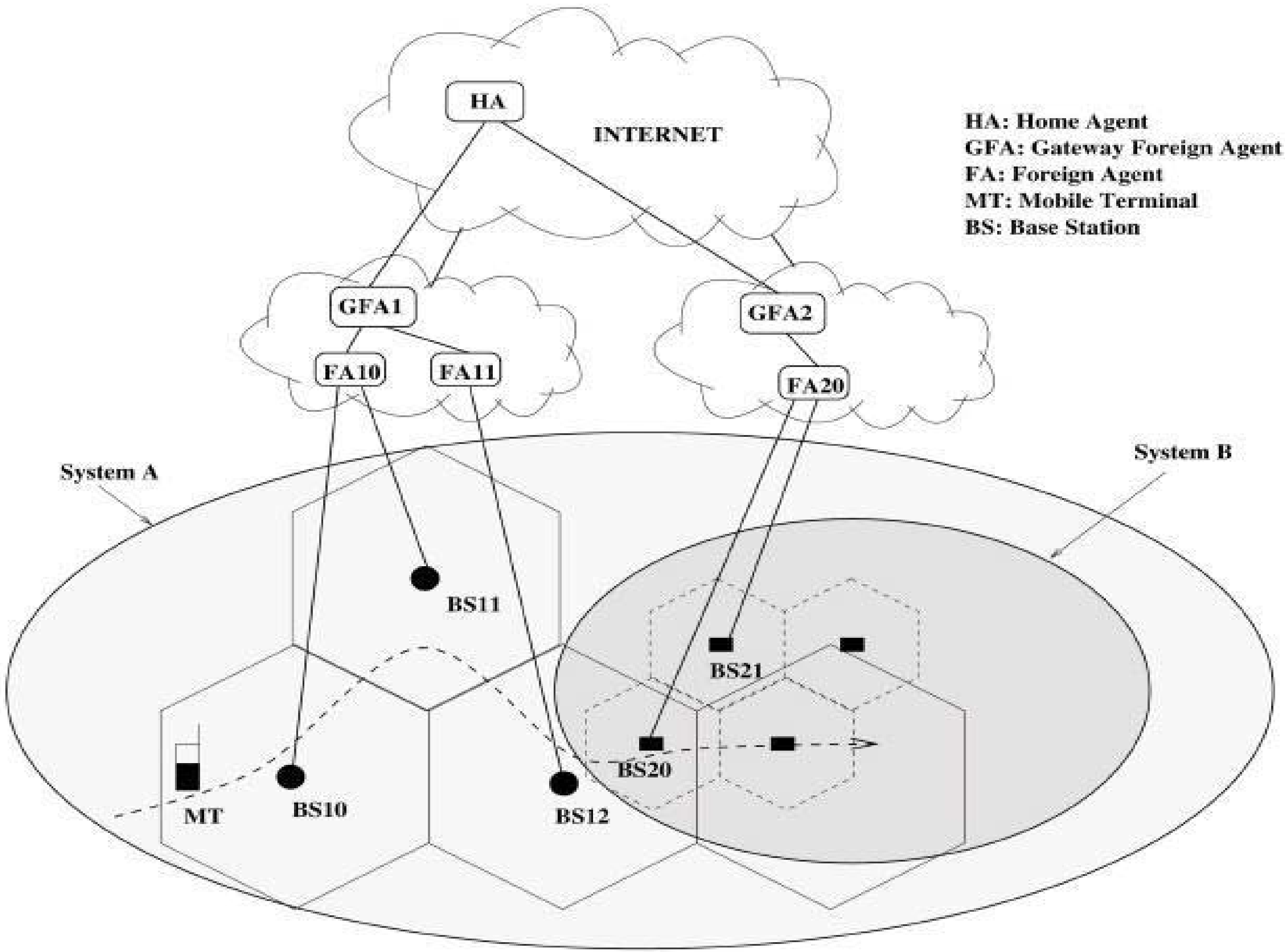


Fig.1 Handoff in the integrated NGWS architecture

Mobility management in the NGWS

- The efficient intra and intersystem handoff protocols should have the following characteristics to support seamless handoff in NGWS：
  - Minimum handoff latency.
  - Low packet loss.
  - Limited handoff failure

Mobility management in the NGWS

- Handoff management procotols operate from different layers of the TCP/IP protocol stack.
  - Mobile IP
  - TCP-Migrate
  - Session Initiation Protocol

Mobility management in the NGWS

- Mobile IP is simple to implement, but has several shortcomings：
  - Triangular routing
  - High global signaling load
  - High handoff latency
- Mobile IP route optimization eliminates the triangular routing problem.
- Hierarchical Mobile IP is to localize the signaling message to one domain, but fail to address the problem of handoff requirement detection delay.

Mobility management in the NGWS

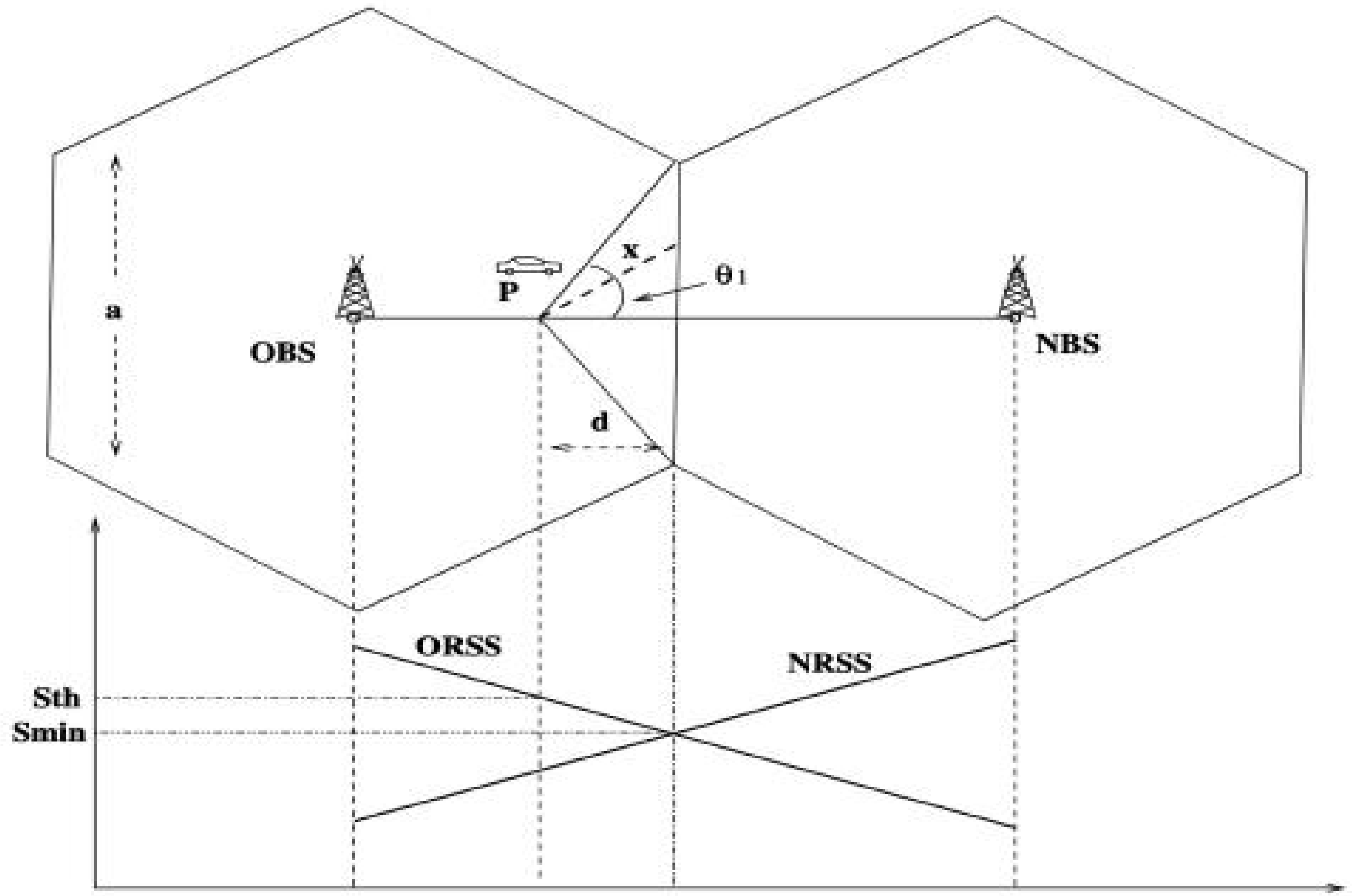
- Using link layer information is able to reduce the handoff requirement detection delay.
- The idea is to use link layer information to anticipate the possibility of an intra or intersystem handoff in advance so that the handoff procedures can be carried out successfully.
- Different link-layer-assisted handoff algorithms that use received signal strength(RSS) information to reduce handoff latency and handoff failure probability.

Mobility management in the NGWS

- Most existing link-layer-assisted handoff protocols assume that the handoff latency of the intra and intersystem handoffs are constant.
- Based on this assumption, these protocols initiate a handoff when the RSS of the serving BS drops below a predefined fixed threshold value.
- Assuming a fixed signaling delay.
- Not considering the influence of user’s speed.

Effect of layer 2 and layer 3 parameters on the performance of handoff management protocols

- Analyzing the performance of the existing network layer handoff management protocol, Hierarchical Mobile IP(HMIP), with respect to its sensitivity to the link layer(Layer 2),e.g., user’s speed, and network layer(Layer 3),e.g.,handoff signaling delay parameters.



Sth: The threshold value of the RSS to initiate the HMIP handoff process.

Smin: The minimum value of RSS required for successful communication between an MT and OBS.

Effect of layer 2 and layer 3 parameters

- We consider that the Mobile Terminal(MT) is moving with a speed ν.
- ν is uniformly distributed in $[v_{min}, v_{max}]$
- The probability density function(pdf) of ν ：

$$f_v(v) = \frac{1}{v_{max} - v_{min}} \quad v_{min} < v < v_{max}.$$

Effect of layer 2 and layer 3 parameters

- The pdf of MT's direction of motion θ is

$$f_\theta(\theta) = \frac{1}{2\pi} \quad -\pi < \theta < \pi.$$

- The probability of false handoff initiation is

$$\begin{aligned} p_a &= 1 - \int_{-\theta_1}^{\theta_1} f_\theta(\theta) d\theta \\ &= 1 - \frac{2\theta_1}{2\pi} = 1 - \frac{1}{\pi} \arctan\left(\frac{a}{2d}\right). \end{aligned}$$

Effect of layer 2 and layer 3 parameters

- The time it takes to move out of the coverage area of OBS is given by

$$t = \frac{d \sec \beta}{v}, \text{where } \beta \in [(-\theta_1, \theta_1)]$$

- The pdf of t is given by

$$f_t(t) = \begin{cases} \frac{d}{\theta_1 t \sqrt{v^2 t^2 - d^2}}, & \frac{d}{v} < t < \frac{\sqrt{\frac{a^2}{4} + d^2}}{v} \\ 0 & \text{otherwise.} \end{cases}$$

Effect of layer 2 and layer 3 parameters

- The probability of handoff failure is given by

$$p_f = \begin{cases} 1 & \tau > \frac{\sqrt{\frac{a^2}{4}+d^2}}{v} \\ p(t < \tau) & \frac{d}{v} < \tau < \frac{\sqrt{\frac{a^2}{4}+d^2}}{v} \\ 0 & \tau \leq \frac{d}{v}, \end{cases}$$

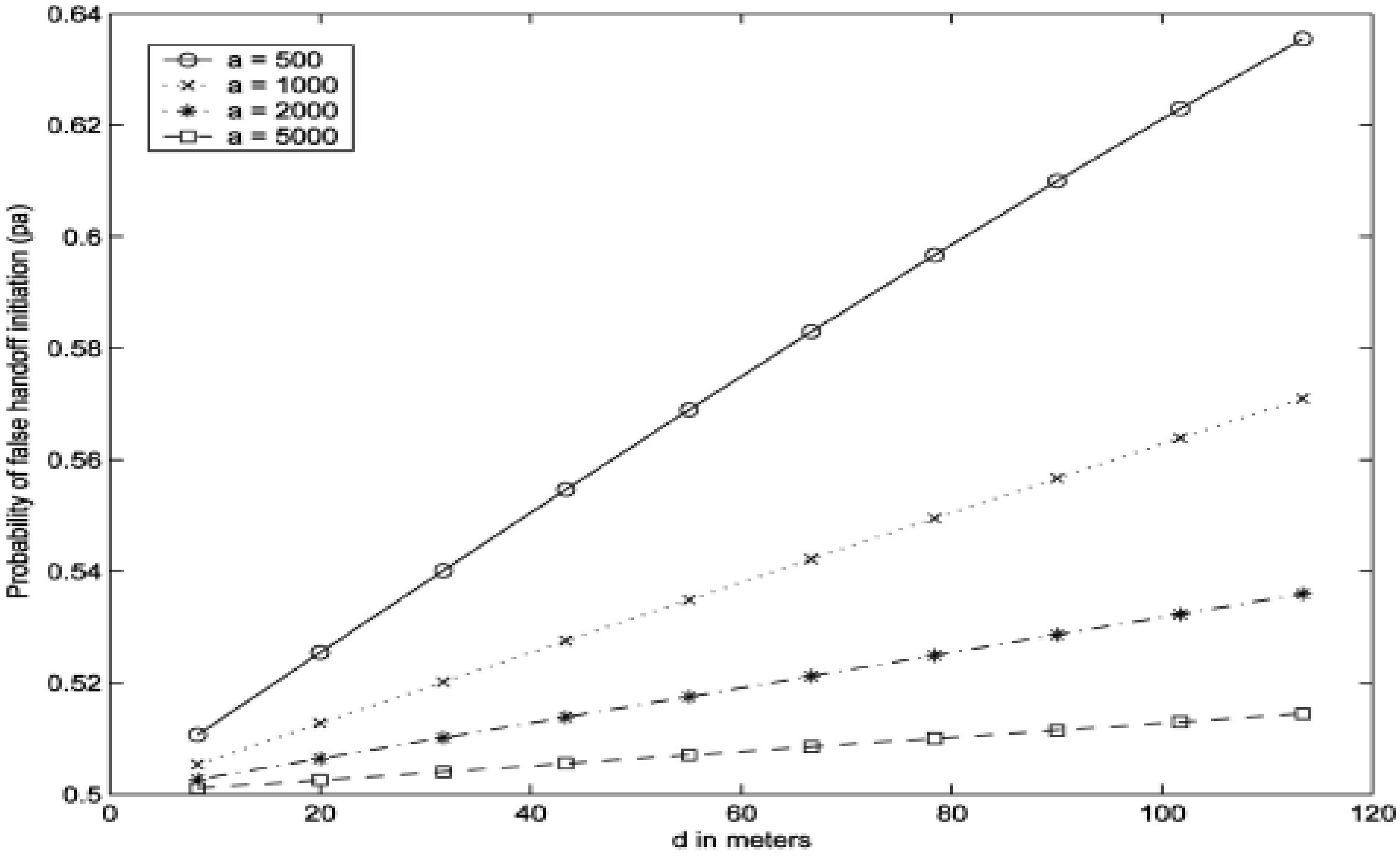
,where τ is the handoff signaling delay

$$\begin{aligned} p(t < \tau) &= \int_0^{\tau} f_t(t)dt \\ &= \int_{\frac{d}{v}}^{\tau} \frac{d}{\pi t\sqrt{v^2t^2 - d^2}}dt \\ &\approx \frac{1}{\theta_1}\arccos\left(\frac{d}{v\tau}\right). \end{aligned}$$

Effect of layer 2 and layer 3 parameters

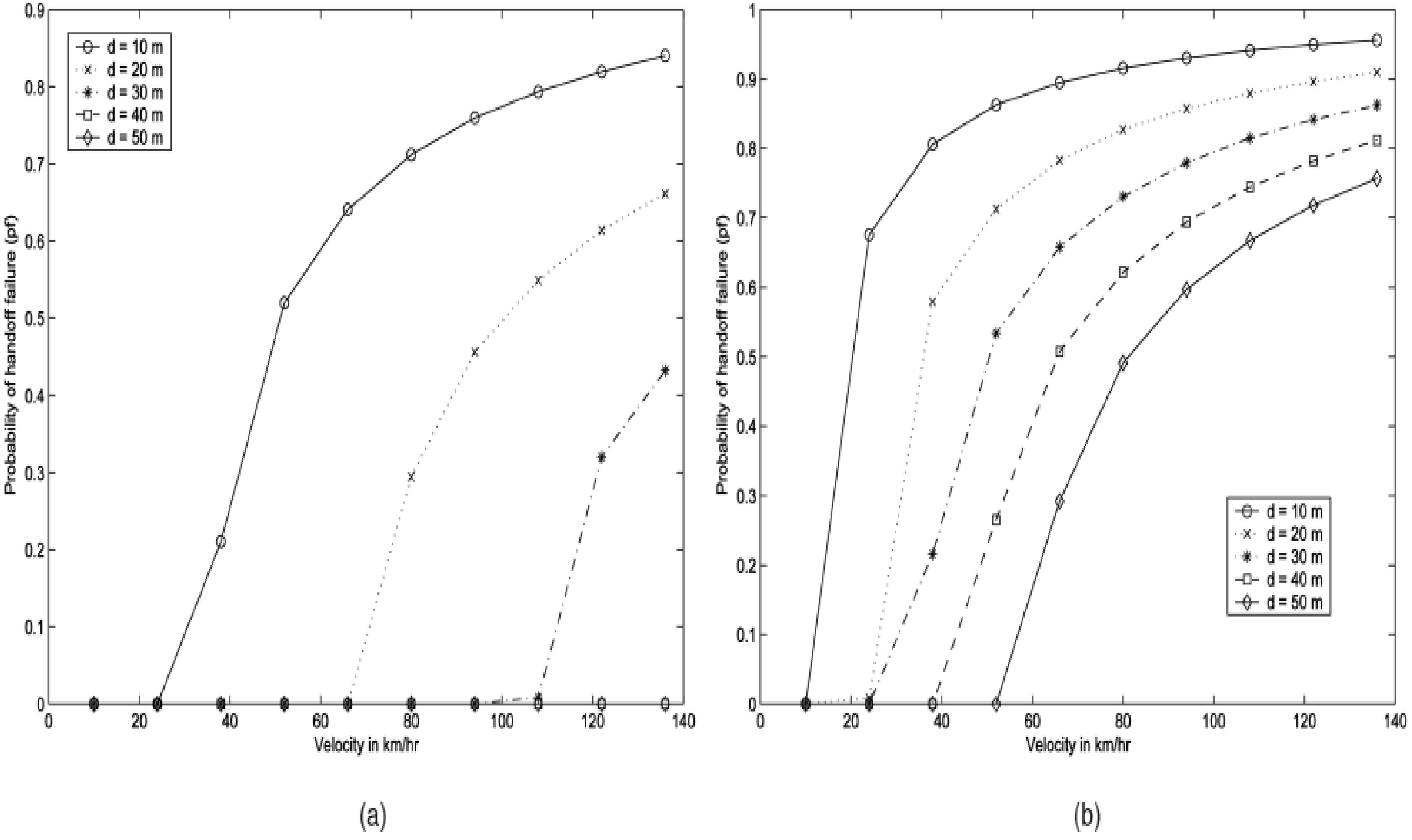
- So, the probability of handoff failure is

$$p_f = \begin{cases} 1 & \tau > \frac{\sqrt{\frac{a^2}{4}+d^2}}{v} \\ \frac{1}{\theta_1}\arccos\left(\frac{d}{v\tau}\right) & \frac{d}{v} < \tau < \frac{\sqrt{\frac{a^2}{4}+d^2}}{v} \\ 0 & \frac{d}{v} \geq \tau. \end{cases}$$

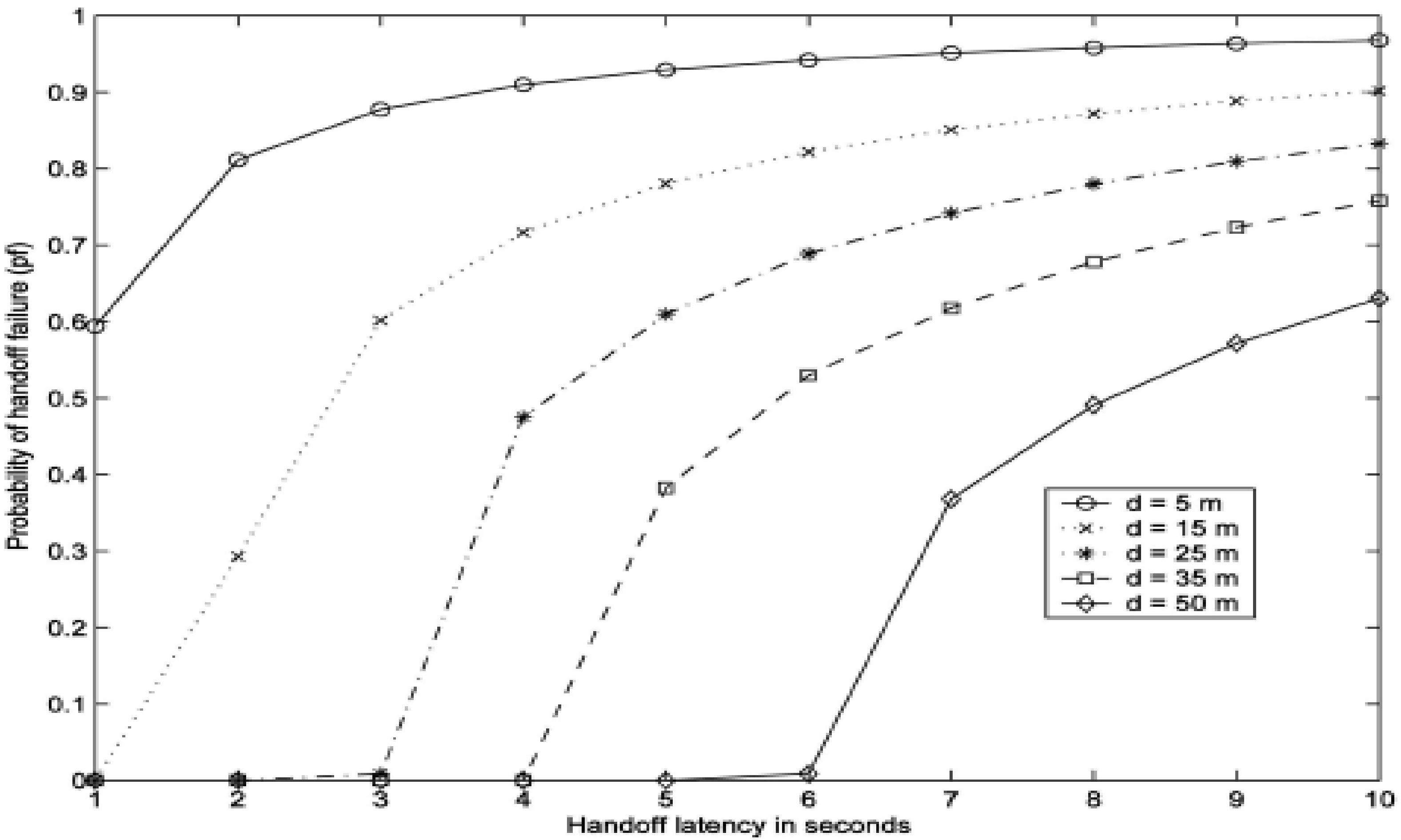


This picture shows that,if a fixed value of S_{th} (hence, a fixed value of corresponding d) is used, the handoff failure probability depends on the speed of MT.

It is important to select the proper value of d to reduce the false handoff initiation probability.



(a)for intrasystem handoff with τ =1sec (b)for intersystem handoff with τ =3 sec



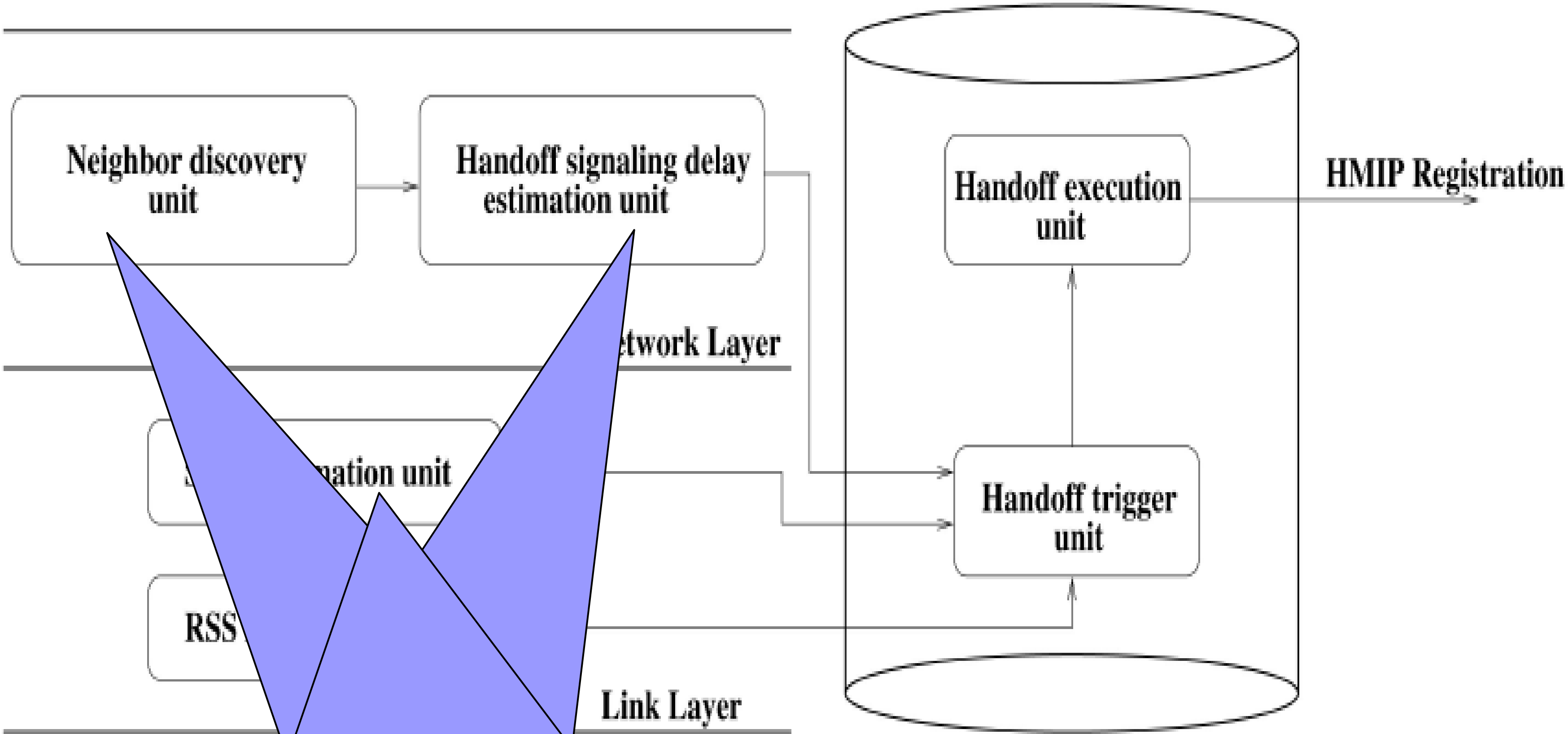
It is essential to predict handoff signaling delay in advance and accordingly use an adaptive value for S_{th}.

Effect of layer 2 and layer 3 parameters

- The analysis above shows that an unnecessarily large value of S_{th} should not be used as it increases the probability of false handoff initiation, and affects the performance of the system negatively.
- Using adaptive S_{th} that depends on MT's speed and handoff signaling delay at particular time.

Cross-Layer Handoff Management Protocol(CHMP)

- The proposed handoff management protocol using information derived from different layers of TCP/IP protocol stack(e.g.,speed information from link layer and handoff signaling delay information from network layer) is called CHMP.



The module estimates mobile's speed using the velocity estimation using the power spectral density of the received signal envelope(called VEPSD).

Cross-Layer Handoff Management Protocol(CHMP)

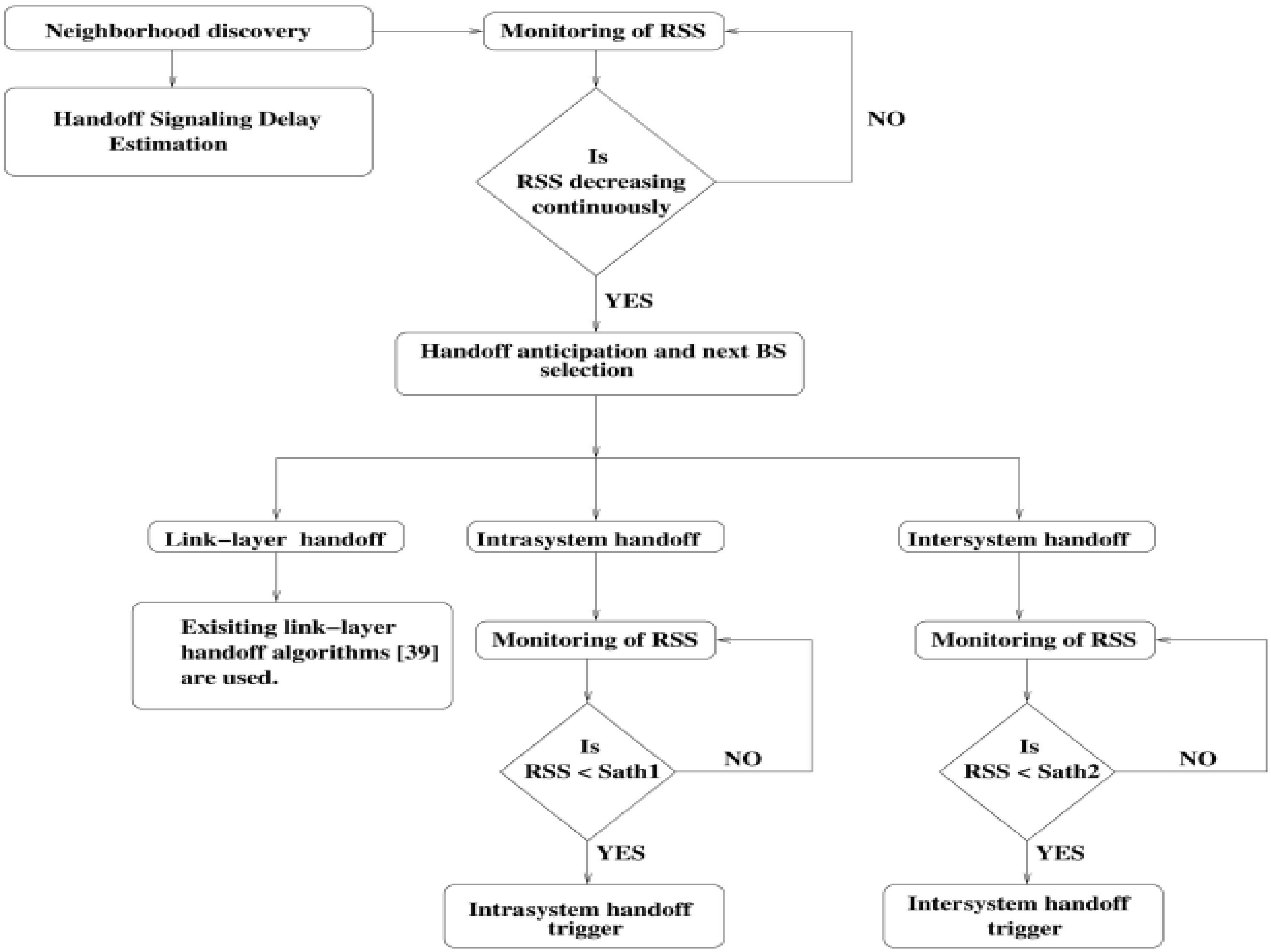
- Once d is calculated, the corresponding S_{ath} is calculated using the path model and the cell size of the serving BS.

$$P_r(x) = P_r(d_0)\left(\frac{d_0}{x}\right)^{\alpha} + \epsilon$$

,where α is path-loss cofficient

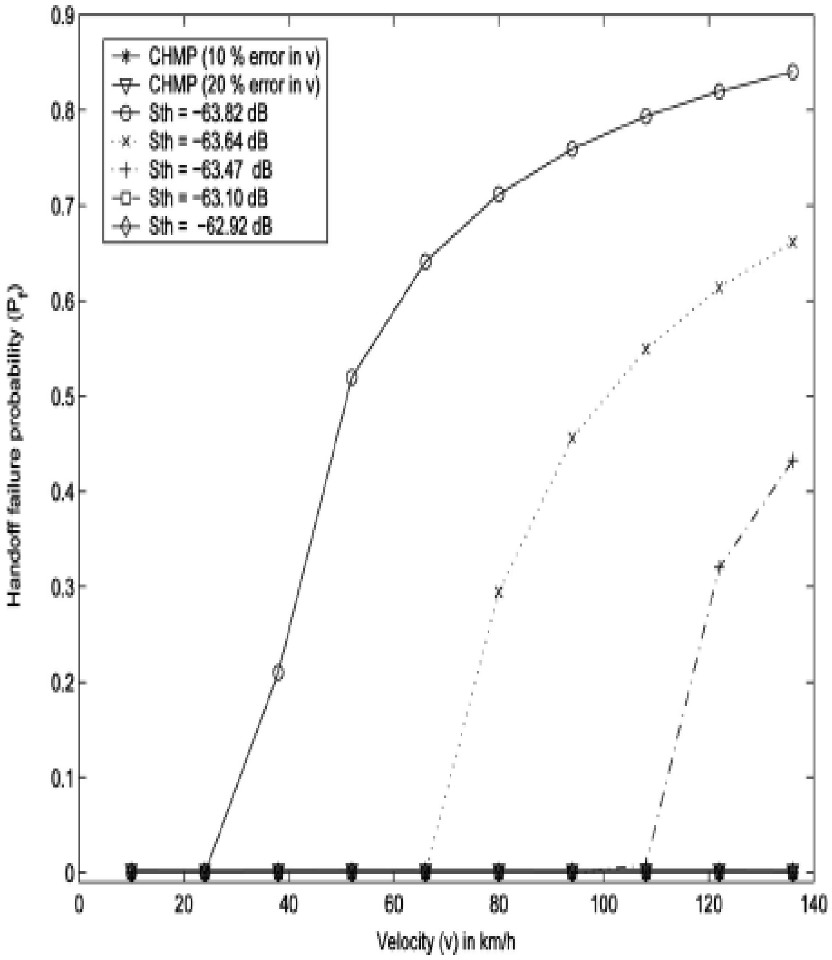
- The RSS value when the MT is at a d distance from the cell boundary is given by

$$S_{ath} = 10\log_{10}[P_r(a-d)]$$

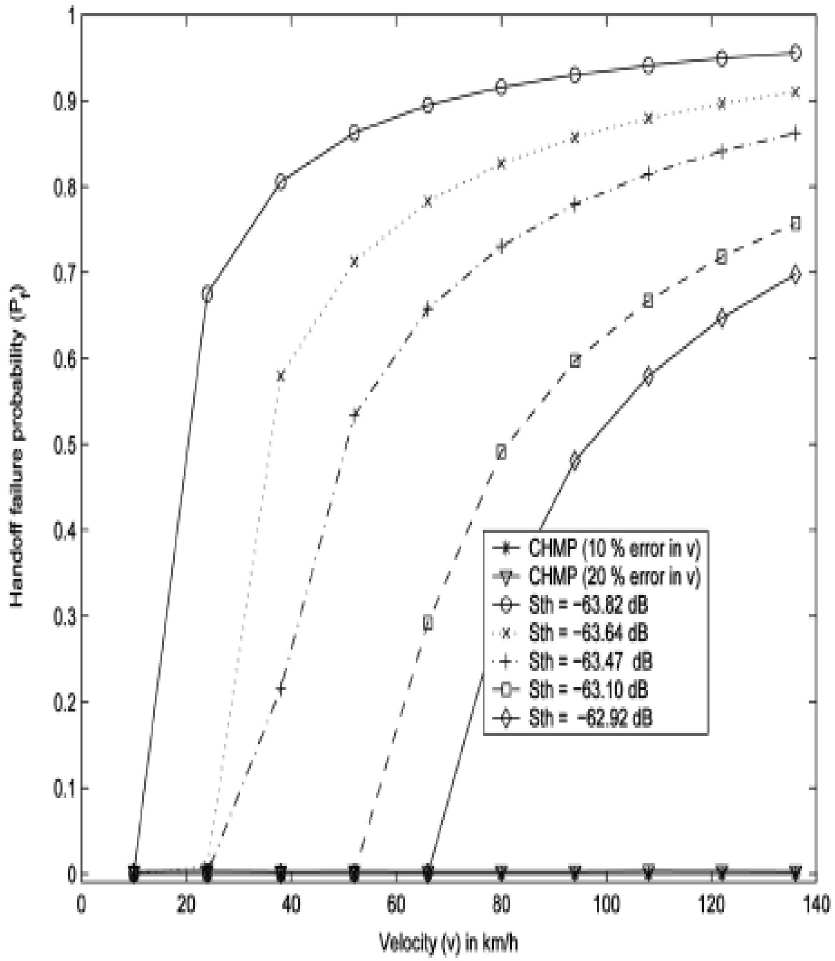

Neighborhood discovery
Monitoring of RSS
Handoff Signaling Delay Estimation
NO
Is RSS decreasing continuously
YES
Handoff anticipation and next BS selection
Link−layer handoff
Intrasystem handoff
Intersystem handoff
Exisiting link−layer handoff algorithms [39] are used.
Monitoring of RSS
Monitoring of RSS
Is RSS < Sath1
NO
Is RSS < Sath2
NO
YES
YES
Intrasystem handoff trigger
Intersystem handoff trigger

Performance evaluation of CHMP

- Microcelluar system：
  - Cell size=1 km
  - d_0 = 100m
  - S_{min} = -64 dBm
  - α = 4
- Macrocelluar system：
  - Cell size=30 m
  - d_0 = 1m
  - S_{min} = -64 dBm
  - α = 4


CHMP (10 % error in v)
CHMP (20 % error in v)
Sth = -63.82 dB
Sth = -63.64 dB
Sth = -63.47 dB
Sth = -63.10 dB
Sth = -62.92 dB
Handoff failure probability (P_f)
Velocity (v) in km/h

(a)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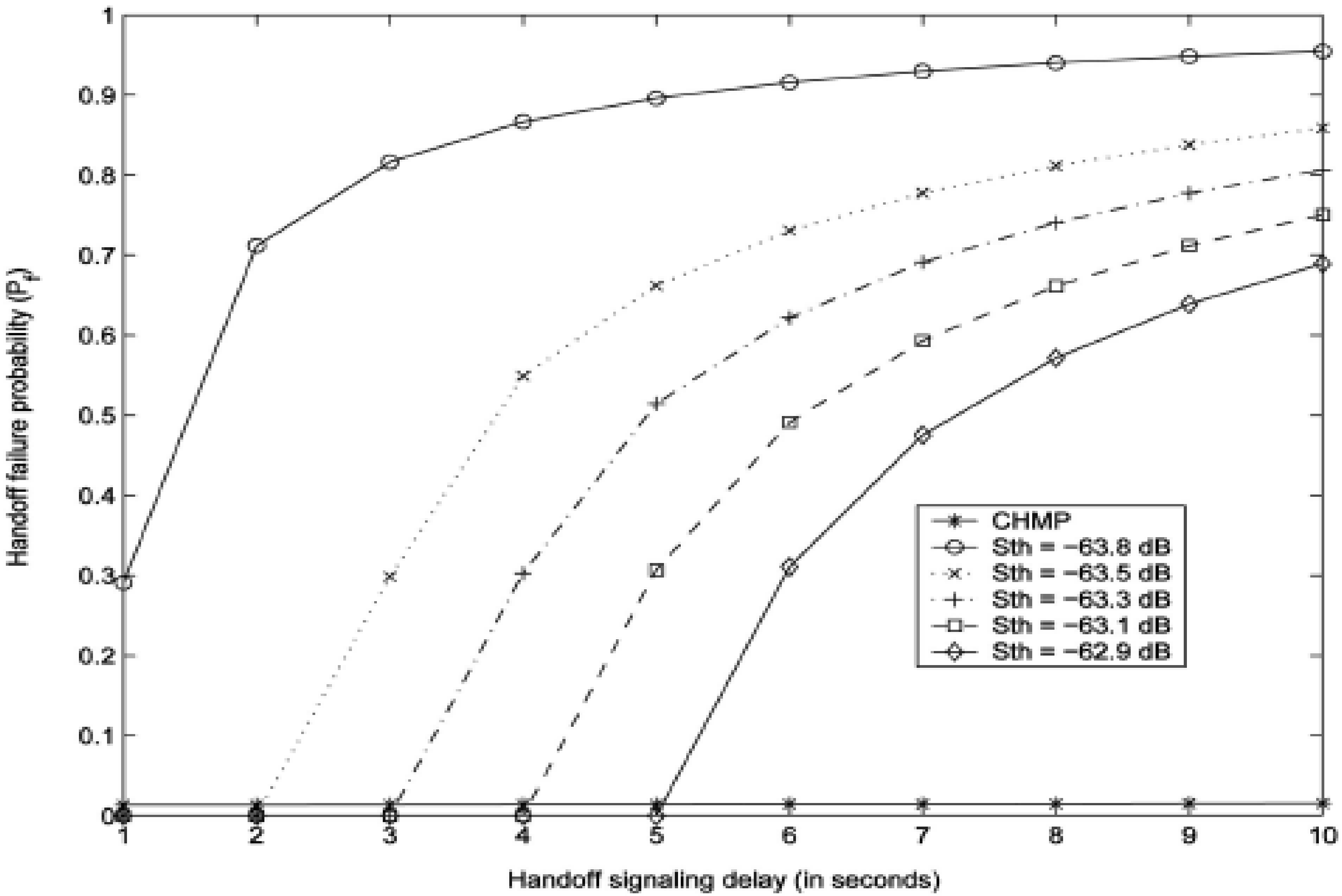
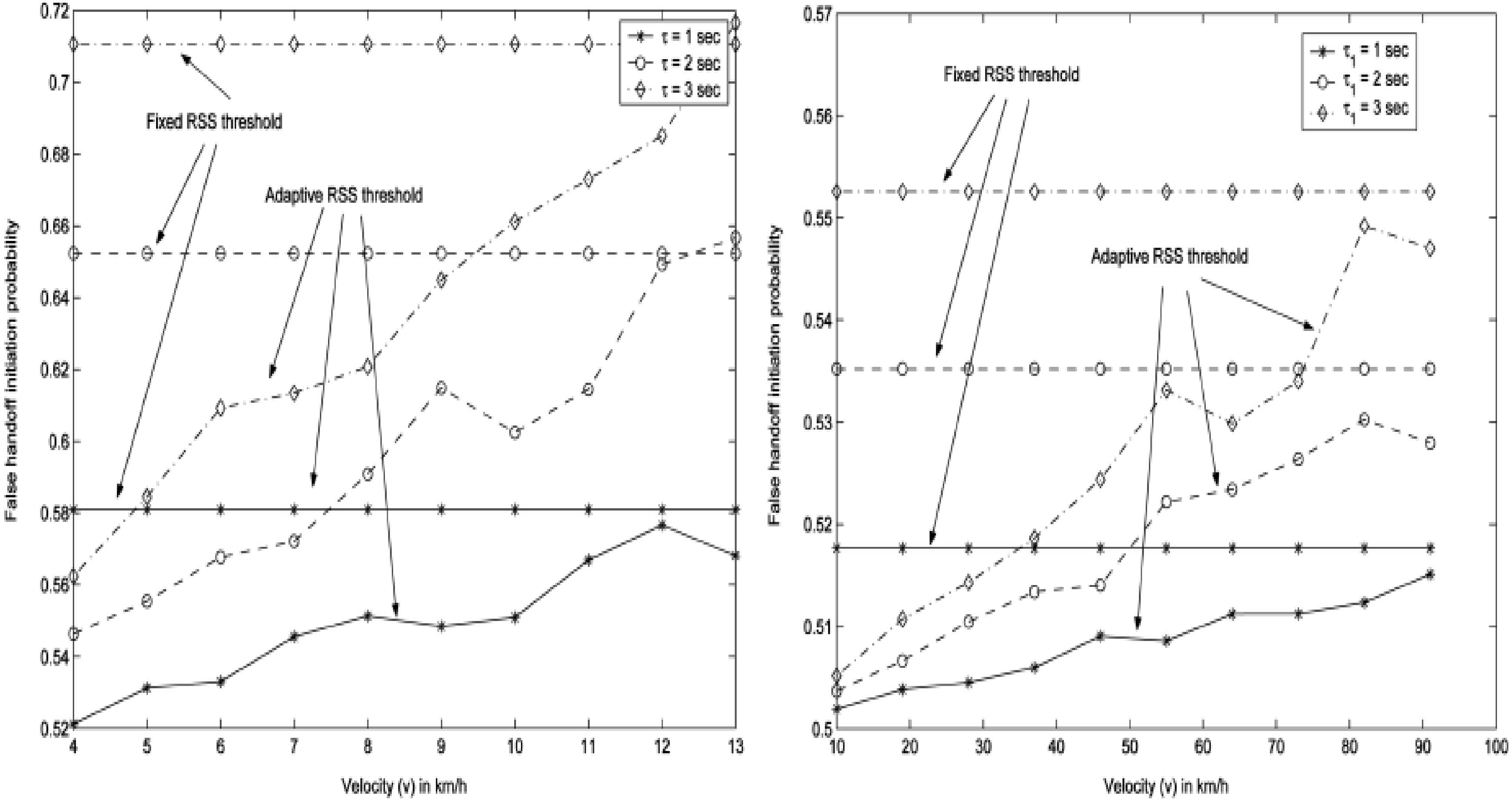
Sth = -62.92 dB
Handoff failure probability (P_f)
Velocity (v) in km/h

(b)


Handoff failure probability (P_f)
Handoff signaling delay (in seconds)
CHMP
Sth = −63.8 dB
Sth = −63.5 dB
Sth = −63.3 dB
Sth = −63.1 dB
Sth = −62.9 dB



τ = 1 sec
τ = 2 sec
τ = 3 sec
Fixed RSS threshold
Adaptive RSS threshold
False handoff initiation probability
Velocity (v) in km/h
τ_1 = 1 sec
τ_1 = 2 sec
τ_1 = 3 sec
Fixed RSS threshold
Adaptive RSS threshold
False handoff initiation probability
Velocity (v) in km/h

(a) (b)

Conclusion

- CHMP significantly enhances the performance of both intra and intersystem handoffs and reduces the cost associated with false handoff initiation because it achieves lower false handoff initiation probability.