A Study on Performance of Hierarchical Mobile IPv6 in IP-based Cellular Networks

IP Based Cellular Network Conference 2003 (IPCN 2003)
Paris, France

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Contents

Introduction (1/2)

- Recent trend in IETF…
  - New working groups
    - MIP4: Mobility for IPv4
    - MIP6: Mobility for IPv6
    - MIPSHOP: MIPv6 Signaling and Handoff Optimization
  - IP Mobility Optimizations (Mob Opts) in IRTF
    - Analysis of Mobile IP Route Optimization considering such parameters as traffic pattern, link conditions, topology etc
    - Alternative mechanisms for discovering a Mobility Anchor Point (MAP) in Hierarchical Mobile IP (HMIP)
    - Evaluation of existing and new mechanisms for discovering, and selecting a target base station and/or router for handover

Introduction (2/2)

- IETF Mobile IP WG
  - Mobile IPv4
    - Low latency handoff [Blon03]
      - draft-ietf-mobileip-lowlatency-handoffs-v4-05.txt, June 2003.
    - Regional registration [Xie02] [Woo03]
      - draft-ietf-mobileip-reg-tunnel-06.txt, March 2002.
  - Mobile IPv6
    - Fast Handover [Pack03a] [Kempf03]
      - draft-ietf-mobileip-fast-mipv6-06.txt, March 2003.
    - Hierarchical Mobile IPv6 [Pack03b]
      - draft-ietf-mobileip-hmipv6-08.txt, June 2003.

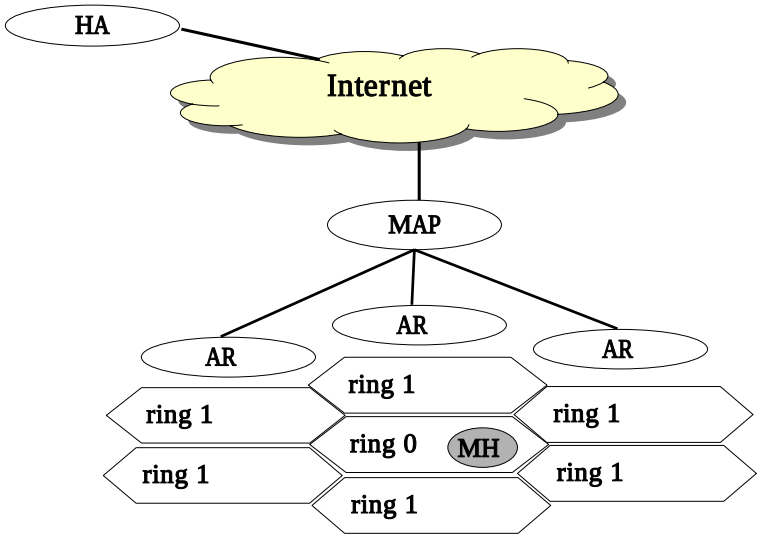
Previous Works (1/2)

- Analytical Model for Cellular Networks
  - A survey of mobility management schemes
    - [Akyi99]
  - Dynamic mobility management [Bar95]
    - Movement-based
    - Timer-based
    - Distance-based
  - Others
    - Pointer forwarding scheme
    - Local anchoring scheme
    - Profile based scheme
    - Probablistic update scheme
    - Replication based scheme

Previous Works (2/2)

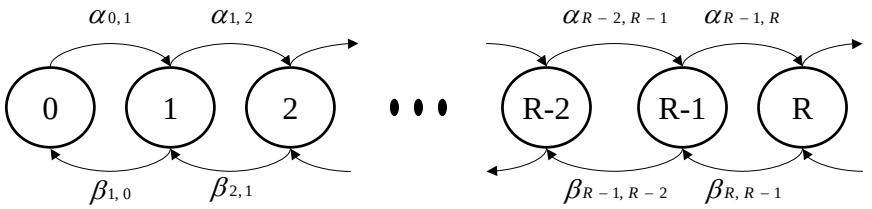
- Analytical Model for IP-based Cellular Networks
  - [Xie02]
    - Analytical model for regional registration
    - Non-geographical mobility model
  - [Woo03]
    - Analytical model for regional registration
    - Fluid-flow model
  - Drawbacks
    - Based on Mobile IPv4 regional registration [Xie02] [Woo03]
      - Hierarchical Mobile IPv6
    - Non-cellular architecture [Xie02]
      - IP-based cellular networks
    - Only fluid-flow model [Woo03]
      - Both random walk model and fluid flow model

Cellular Architecture



Analytic Mobility Model (1/2)

- Random walk model
  - Discrete Time Markov Chain (DTMC)



$$\alpha_{r,r+1} = \begin{cases} 1-q & \text{if } r=0 \\ (1-q)\left(\frac{1}{3}+\frac{1}{6r}\right) & \text{if } 1 \le r \le R \end{cases}$$

$$\beta_{r,r-1} = (1-q)\left(\frac{1}{3}-\frac{1}{6r}\right) \quad \text{if } 1 \le r \le R$$

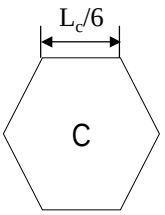
$$\pi_{r,R} = \frac{\prod_{i=0}^{r-1}\frac{\alpha_{i,i+1}}{\beta_{i+1,i}}}{1+\sum_{r=1}^{R}\prod_{i=0}^{r-1}\frac{\alpha_{i,i+1}}{\beta_{i+1,i}}} \quad \text{for } 1 \le r \le R$$

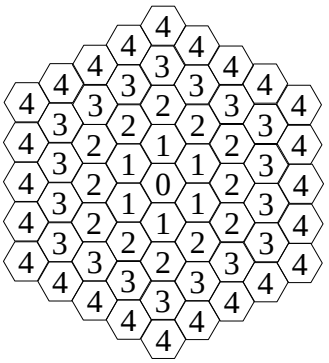
Analytic Mobility Model (2/2)

- Fluid flow model

$$R_c = \frac{\rho v L_c}{\pi} \quad \text{and} \quad R_d = \frac{\rho v L(R)}{\pi}$$

$$L(R) = 6 \times (2R + 1) \times \frac{L_c}{6}$$





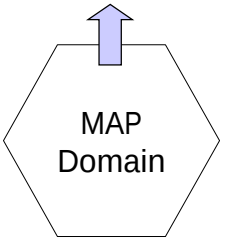
Cost Function (1/2)

- Location update cost
  - Random-walk model

$$C_{location} = \frac{\pi_R \alpha_{R,R+1} C_g + (1 - \pi_R \alpha_{R,R+1}) C_l}{E(T)}$$

  - Fluid-flow model

$$C_{location} = \frac{R_d \cdot C_g + (N_{AR} \cdot R_c - R_d) \cdot C_l}{\rho \cdot A(R)}$$



Cost Function (2/2)

- Packet delivery cost
  - Processing cost at the MAP

$$C_{MAP} = \lambda_s \cdot E(S) \cdot (C_{lookup} + C_{routing}) = \lambda_s \cdot E(S) \cdot (\alpha N_{MN} + \beta \log(N_{AR}))$$

  - Processing cost at the HA

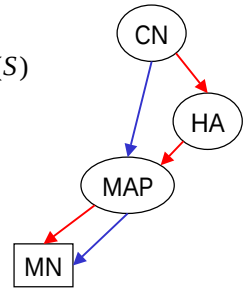
$$C_{HA} = \lambda_s \cdot \theta_{HA}$$

  - Transmission cost

$$C_T = \tau \cdot \lambda_s \cdot ((E(S)-1) \cdot (D_{CN-MAP} + D_{MAP-AR}) + (D_{CN-HA} + D_{HA-MAP} + D_{MAP-AR})) + \kappa \cdot \lambda_s \cdot E(S)$$

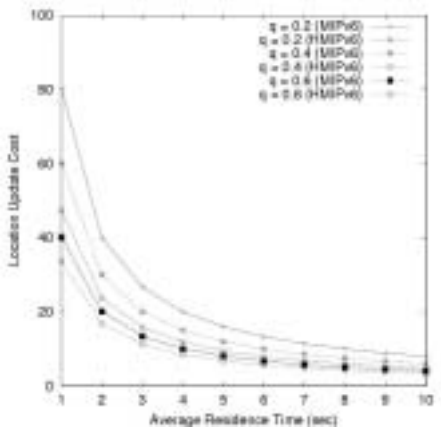
  - Total packet delivery cost

$$C_{packet} = C_{MAP} + C_{HA} + C_T$$

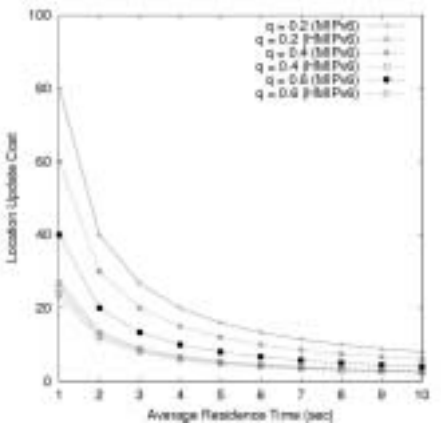


Numerical Result (1/6)

- Location update cost vs. User mobility (Random)



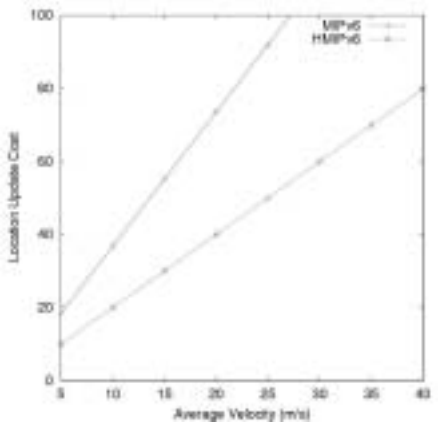
R=1



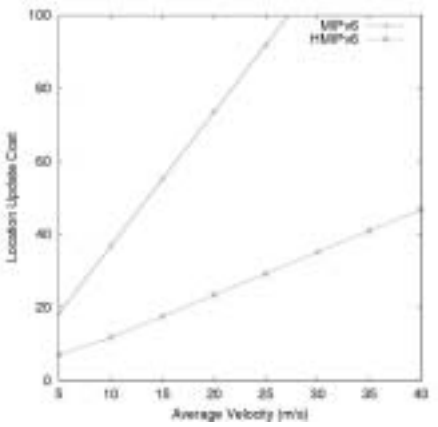
R=4

Numerical Result (2/6)

- Location update cost vs. User mobility (Fluid)



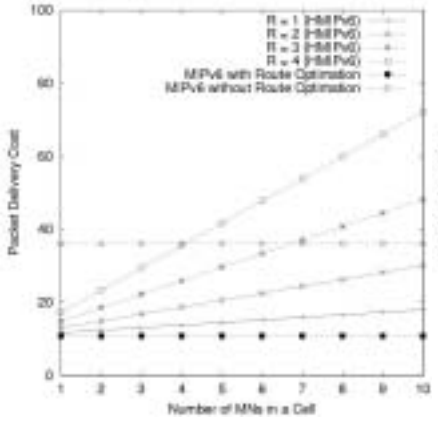
R=1



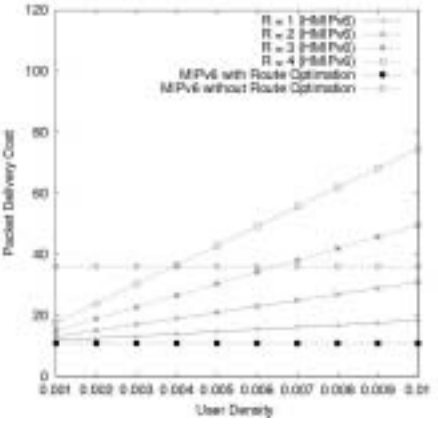
R=4

Numerical Result (3/6)

- Packet delivery cost vs. User population



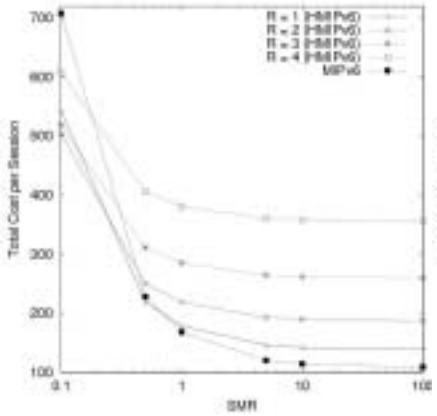
Random walk model



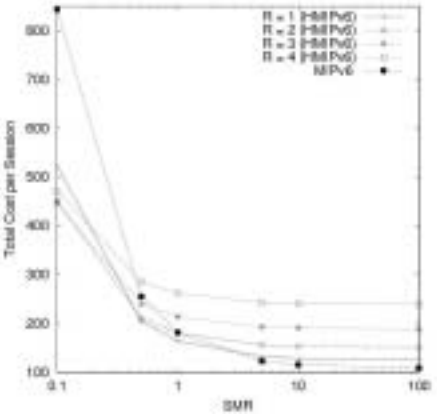
Fluid flow model

Numerical Result (4/6)

- Total cost vs. SMR



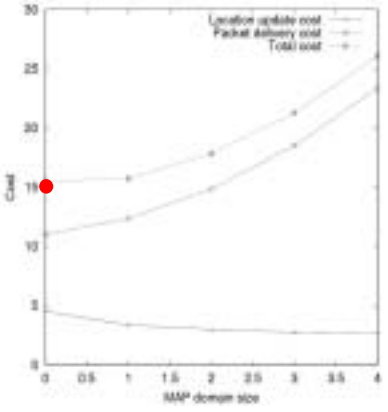
Random walk model



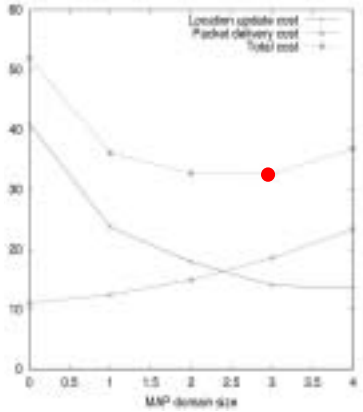
Fluid flow model

Numerical Result (5/6)

- Optimal domain size (Random)



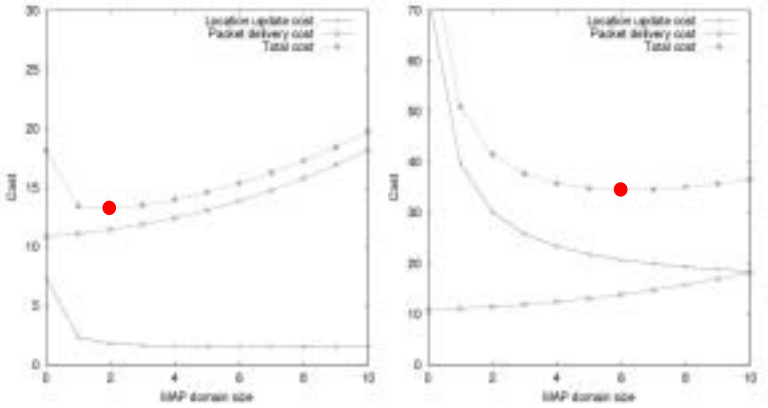
Static MN



Dynamic MN

Numerical Result (6/6)

- Optimal domain size (Fluid)



Static MN Dynamic MN

Conclusion

- In this work
  - Performance analysis of HMIPv6
    - Random walk model and fluid flow model
    - Location update cost and packet processing cost
    - Numerical results
- Future works
  - Performance analysis of HMIPv6 with IP paging
  - Performance analysis of HMIPv6 with Fast Handover
  - Enhanced HMIPv6
    - Adaptive HMIPv6 for Optimal MAP selection
    - Robust Hierarchical Mobile IPv6 (RH-MIPv6) [Pack03c]

References (1/2)

- **[Pack03a]** S. Pack and Y. Choi, "Performance Analysis of Fast Handover in Mobile IPv6 Networks, " in *Proc. IFIP PWC 2003*, Venice, Italy, Sep. 2003.
- **[Pack03b]** S. Pack and Y. Choi, "Performance Analysis of Hierarchical Mobile IPv6 in IP-based Cellular Networks," in *Proc. IEEE PIMRC 2003*, Beijing, China, Sep. 2003.
  - Journal Version: S. Pack and Y. Choi, "A Study on Performance of Hierarchical Mobile IPv6 in IP-based Cellular Networks," *IEICE Transactions on Communications*, Vol. E87-B, No. 3, March 2003.)
- **[Pack03c]** T. You, S. Pack, and Y. Choi, "Robust Hierarchical Mobile IPv6 (RH-MIPv6): An Enhancement for Survivability & Fault Tolerant Mobile IP Systems," in *Proc. IEEE VTC-Fall 2003*, Orlando, USA, Oct. 2003.

References (2/2)

- **[Blon03]** C. Blondia et al., "Performance Comparison of Low Latency Mobile IP Schemes, " in *Proc. of WiOpt 2003*, March 2003.
- **[Xie03]** J. Xie and I. F. Akyildiz, "A Distributed Dynamic Regional Location Management Scheme for Mobile IP," *IEEE Transactions on Mobile Computing*, Vol. 1, No. 3, July 2002.
- **[Woo03]** M. Woo, "Performance Analysis of Mobile IP Regional Registration," *IEICE Transactions on Communications*, Vol. E86-B, No. 2, Feb. 2003.
- **[Kempf03]** J. Kempf et al., "Fast Mobile IPv6 Handover Packet Loss Performance-Measurements for Emulated Real Time Traffic," in *Proc. of IEEE WCNC 2003*, May 2003.
- **[Akyi99]** I. F. Akyildiz et al., "Mobility Management in Next-Generation Wireless System," *Proc. of IEEE*, Vol. 87, No. 8, Aug. 1999.
- **[Bar95]** A. Bar-Noy, "Mobile users: To update of not update?," *ACM/Baltzer J. Wireless Networks*, Vol. 1, No. 2, July 1995.