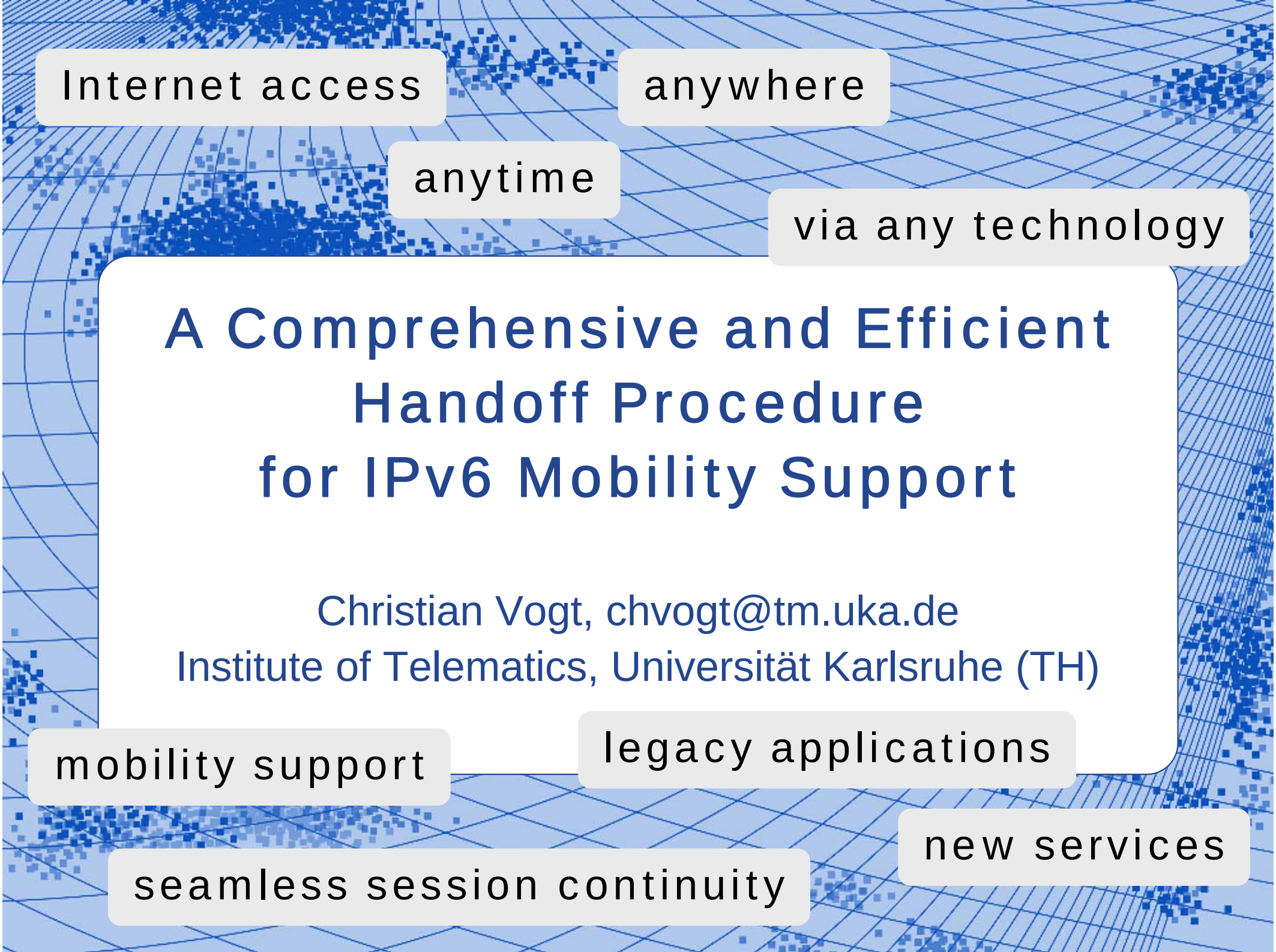
A Comprehensive and Efficient Handoff Procedure for IPv6 Mobility Support

Christian Vogt, chvogt@tm.uka.de
Institute of Telematics, Universität Karlsruhe (TH)


Internet access
anywhere
anytime
via any technology
A Comprehensive and Efficient Handoff Procedure for IPv6 Mobility Support
Christian Vogt, chvogt@tm.uka.de
Institute of Telematics, Universität Karlsruhe (TH)
mobility support
legacy applications
new services
seamless session continuity

router discovery

address configuration

multicast listener discovery

A Comprehensive and Efficient Handoff Procedure for IPv6 Mobility Support

Christian Vogt, chvogt@tm.uka.de
Institute of Telematics, Universität Karlsruhe (TH)

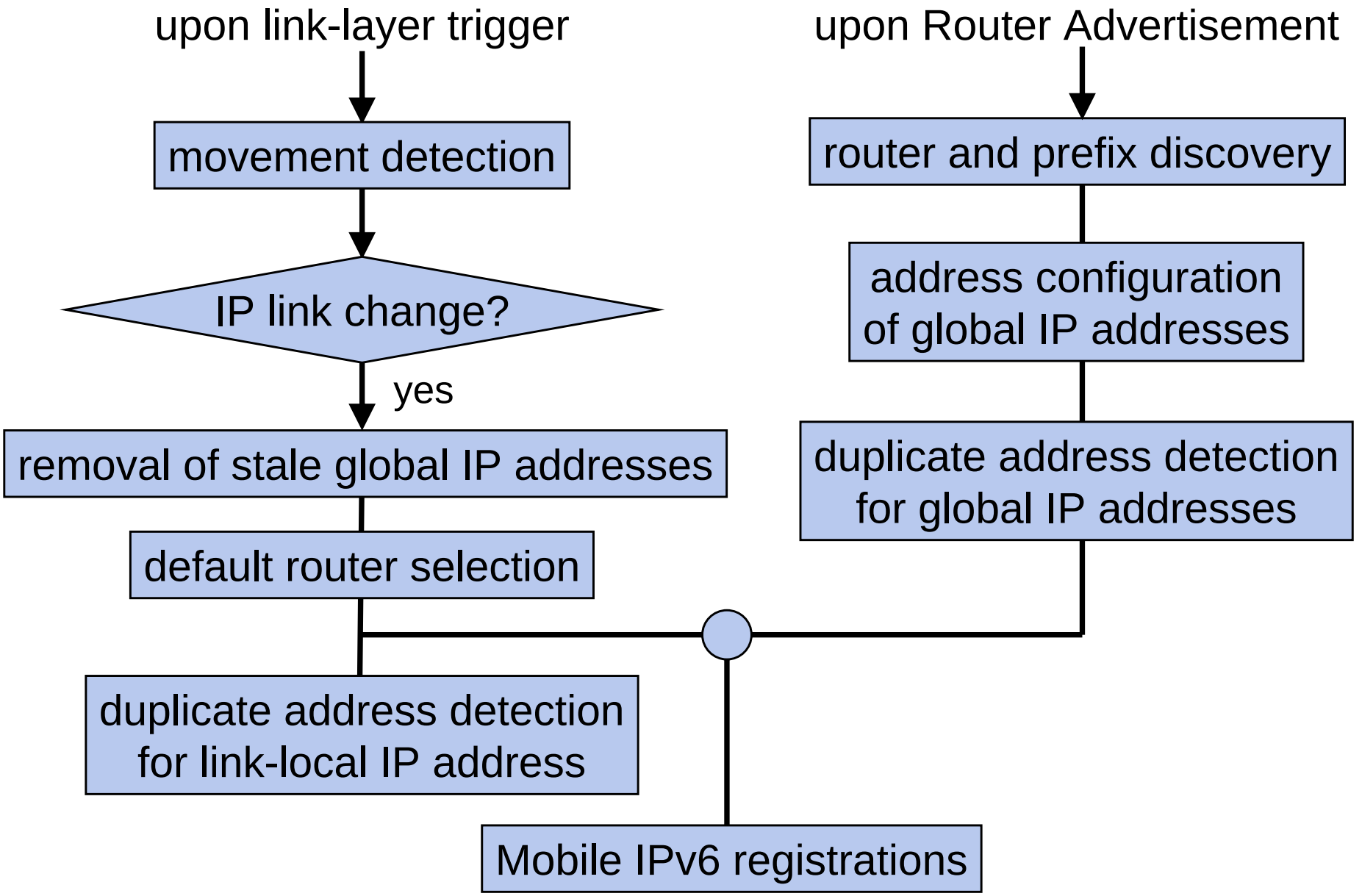
duplicate address detection

neighbor discovery

movement detection

Mobile IPv6

Overall Handoff Procedure

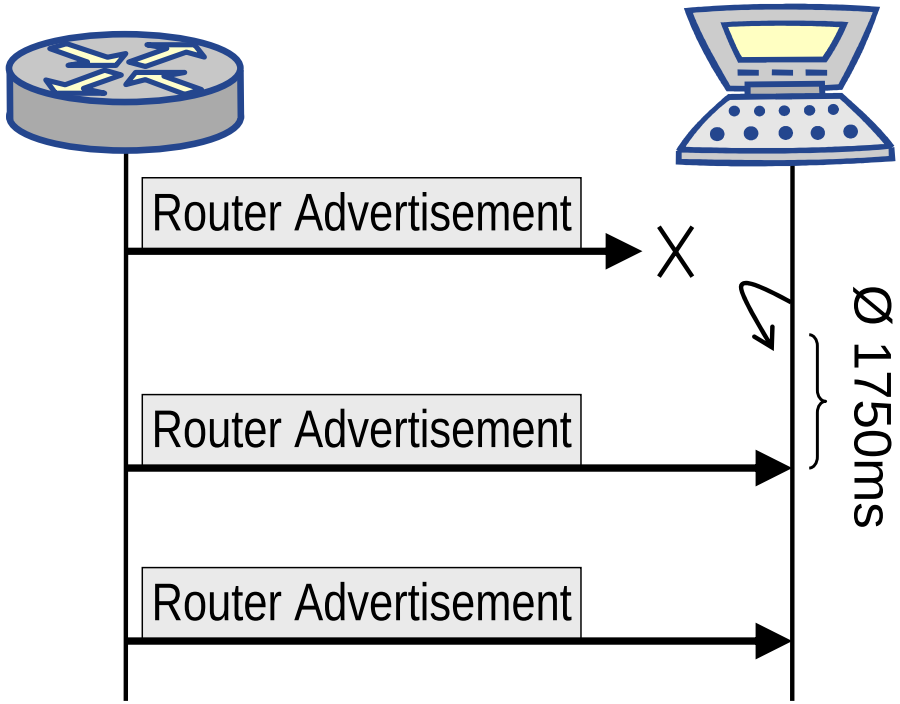


Router Discovery

- To discover routers and on-link prefixes
- Routers advertise this information
  - Periodically in unsolicited Router Advertisements
  - In response to Router Solicitations

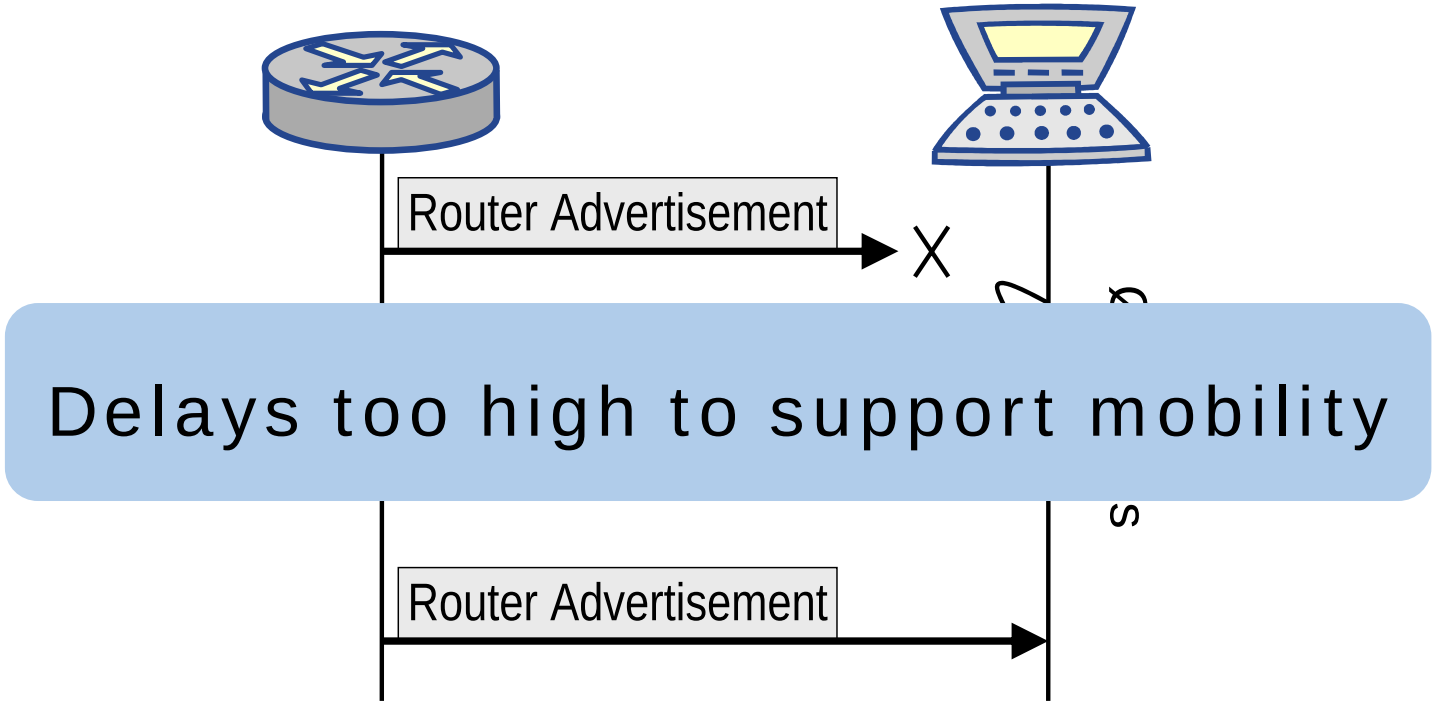
Router Discovery à la RFC 2461

- Intervals for unsolicited Router Advertisements configurable; minimum is 3s~4s
  - Jitter desynchronizes multiple routers on same link
  - Ø 3.5s; receive first Ø 1750ms after handoff



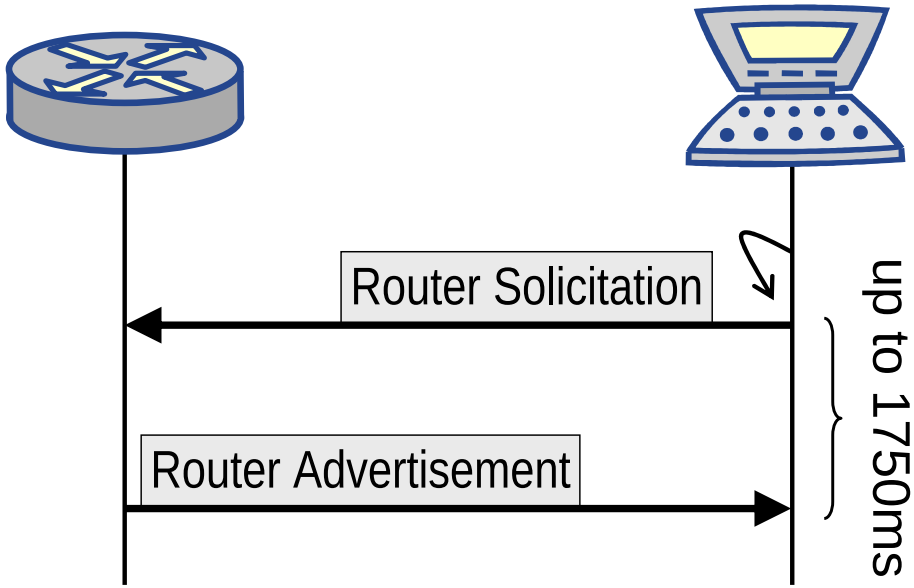
Router Discovery à la RFC 2461

- Intervals for unsolicited Router Advertisements configurable; minimum is 3s~4s
  - Jitter desynchronizes multiple routers on same link
  - Ø 3.5s; receive first Ø 1750ms after handoff



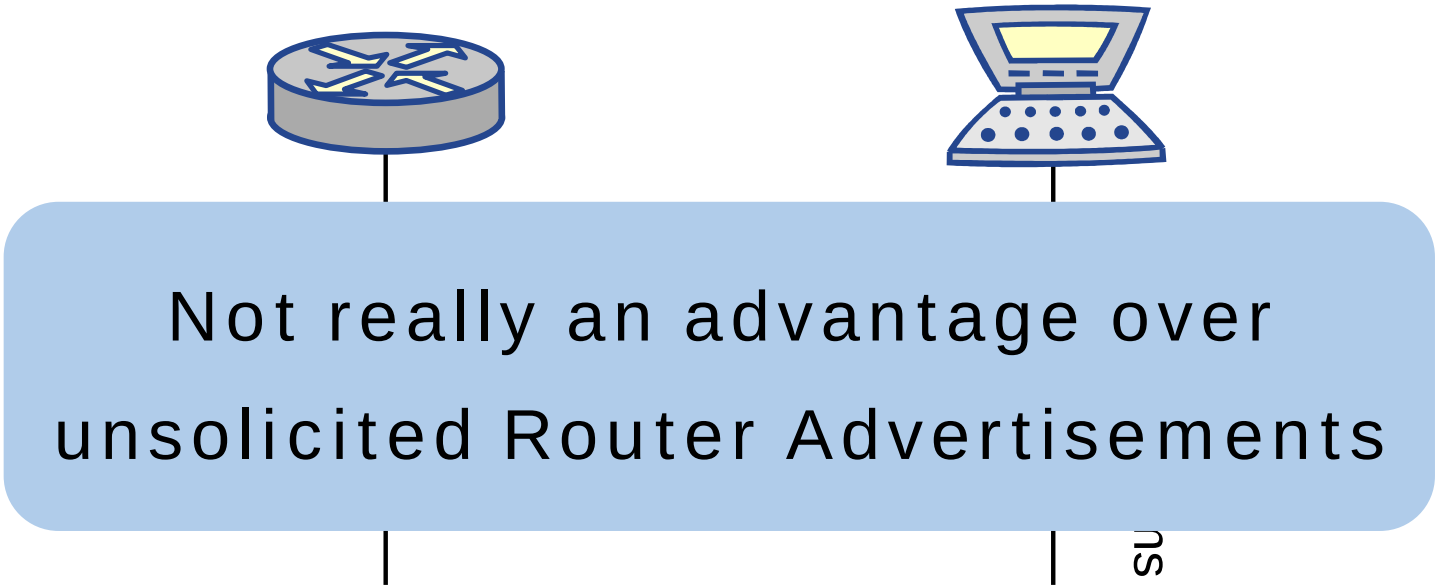
Router Discovery Using Solicitations

- Send Router Solicitation upon handoff
  - Must be sent from unspecified IP address
    - Elicits multicast Router Advertisement
  - Rate limitations (only 1/3s) + 500ms desynchronization
    - Reception Ø 1750ms after handoff when mobility high



Router Discovery Using Solicitations

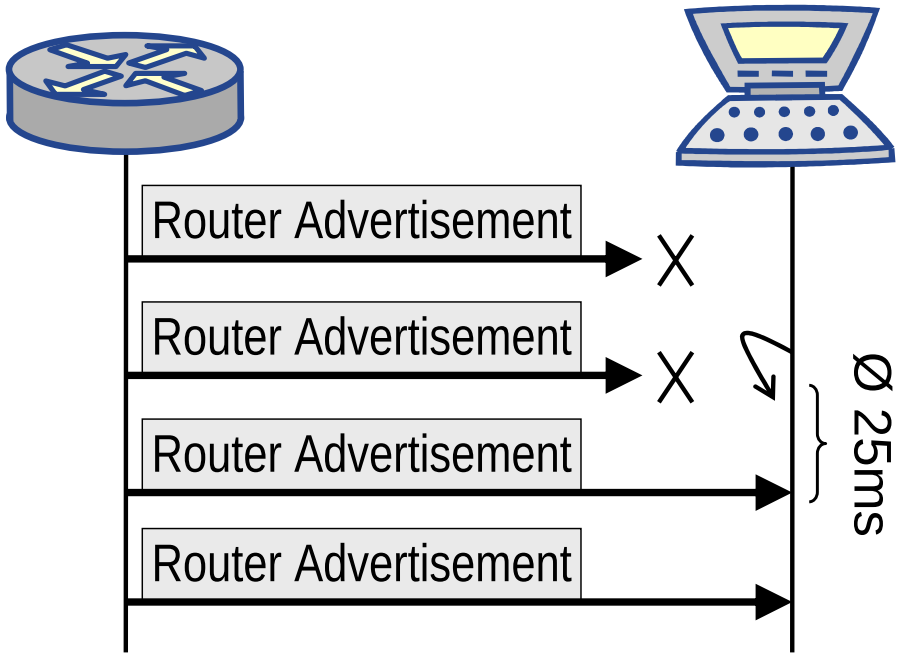
- Send Router Solicitation upon handoff
  - Must be sent from unspecified IP address
    - Elicits multicast Router Advertisement
  - Rate limitations (only 1/3s) + 500ms desynchronization
    - Reception Ø 1750ms after handoff when mobility high



Not really an advantage over unsolicited Router Advertisements

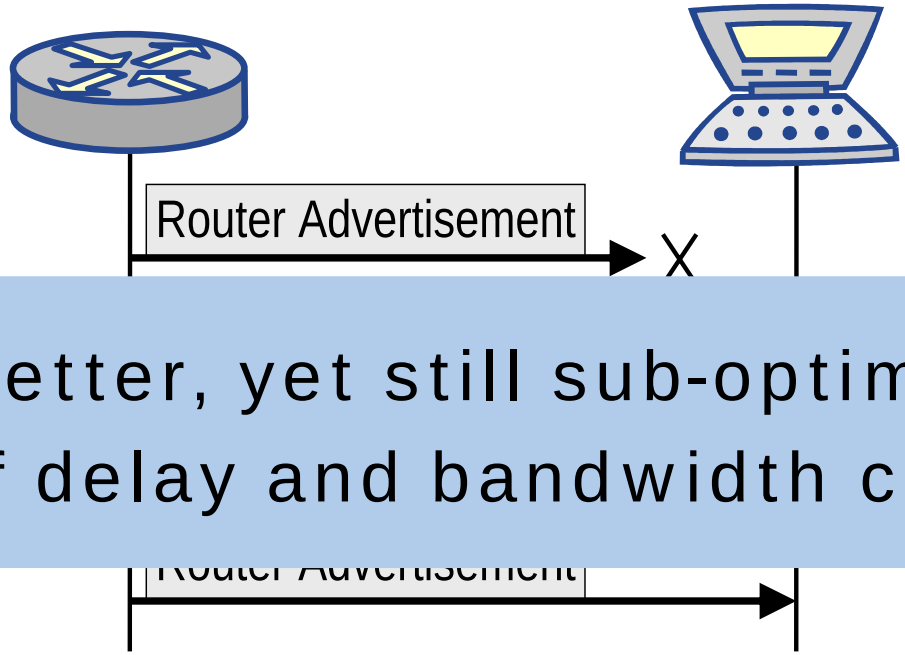
Router Discovery à la RFC 3775

- Router Advertisement intervals 30ms~70ms
  - Ø 50ms; reception Ø 25ms after handoff
  - No comparable improvement for solicited Router Advertisements



Router Discovery à la RFC 3775

- Router Advertisement intervals 30ms~70ms
  - Ø 50ms; reception Ø 25ms after handoff
  - No comparable improvement for solicited Router Advertisements



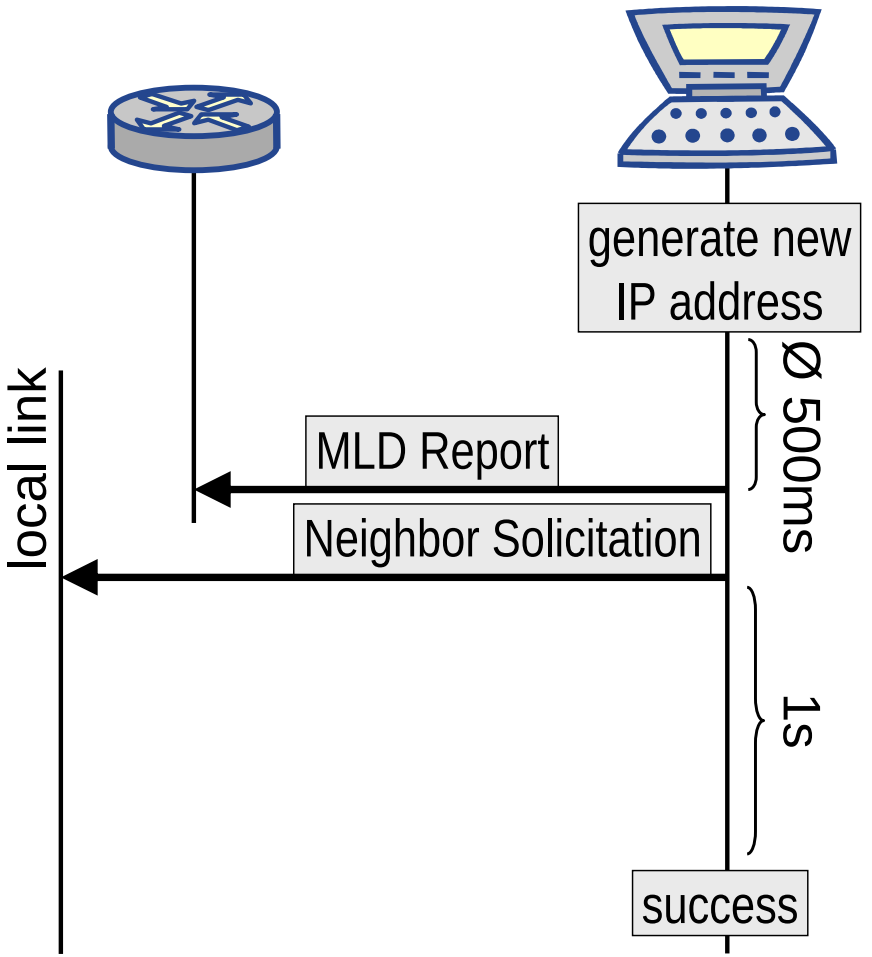
Better, yet still sub-optimal
in terms of delay and bandwidth consumption

Address Configuration

- To configure unicast IP addresses
  - Global address for each new prefix
  - Link-local address upon first network attachment
  - Uniqueness re-verification for link-local address upon change in IP connectivity
- Stateless and stateful variant

Address Configuration à la RFC 2462

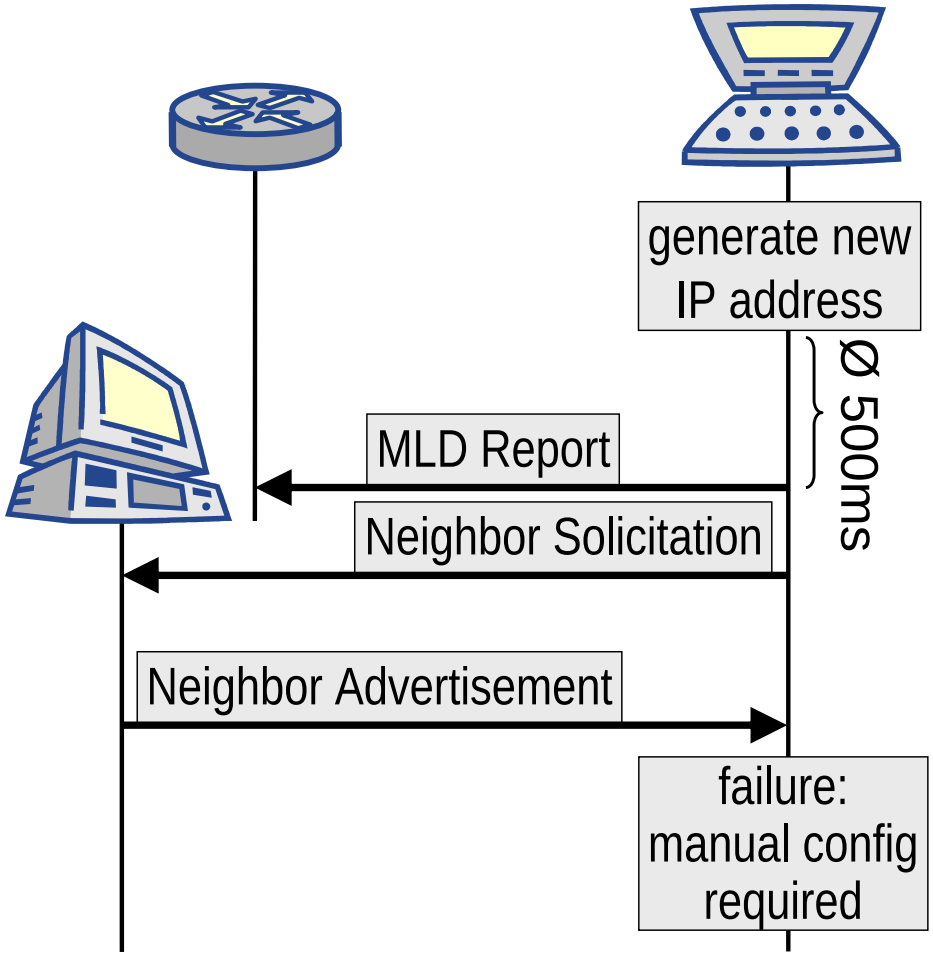
- Generate new IP address
  - Choose interface identifier based on MAC address
  - Prepend on-link prefix
- Send MLD Report for solicited-node multicast address
  - Up to 1s desynchronization between nodes responding to same Router Advertisement
- Duplicate Address Detection
  - Send Neighbor Solicitation
  - Listen for Neighbor Advertisement for 1s
  - Defending node would send Neighbor Advertisement



Successful configuration

Address Configuration à la RFC 2462

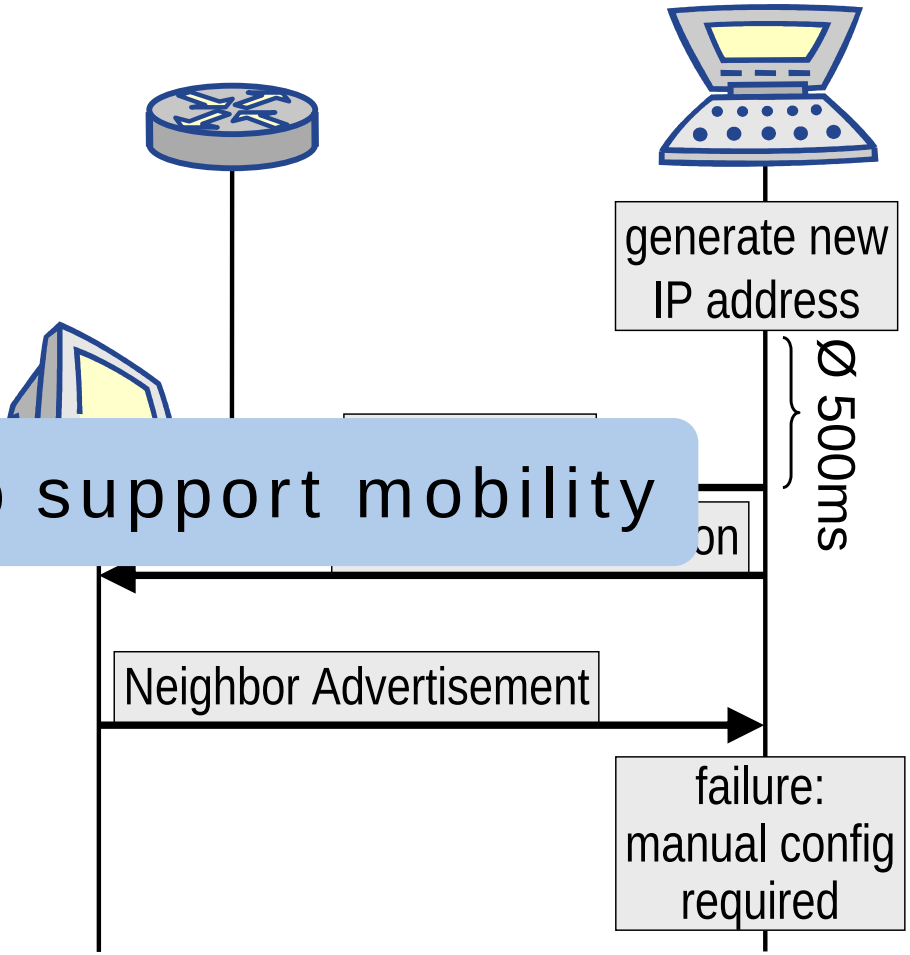
- Generate new IP address
  - Choose interface identifier based on MAC address
  - Prepend on-link prefix
- Send MLD Report for solicited-node multicast address
  - Up to 1s desynchronization between nodes responding to same Router Advertisement
- Duplicate Address Detection
  - Send Neighbor Solicitation
  - Listen for Neighbor Advertisement for 1s
  - Defending node would send Neighbor Advertisement



Failed configuration

Address Configuration à la RFC 2462

- Generate new IP address
  - Choose interface identifier based on MAC address
  - Prepend on-link prefix
- Send MLD Report for solicited-node multicast address
  - Up
    bet
    same Router Advertisement
- Duplicate Address Detection
  - Send Neighbor Solicitation
  - Listen for Neighbor Advertisement for 1s
  - Defending node would send Neighbor Advertisement



Delays too high to support mobility

Failed configuration

Stateful Address Configuration

- DHCPv6 server assigns global address
- High latency
  - Duplicate Address Detection for link-local address first
    - Includes up to 1s desynchronization for MLD Report
  - DHCPv6 servers desynchronize responses for 1.0~1.1s
  - Duplicate Address Detection for global address

Stateful Address Configuration

- DHCPv6 server assigns global address
- High latency
  - Duplicate Address Detection for link-local address first
    - Includes up to 1s desynchronization for MLD Report
  - DHCPv6 servers desynchronize responses for 1.0~1.1s
  - Duplicate Address Detection for global address

Delays even higher than in stateless address configuration

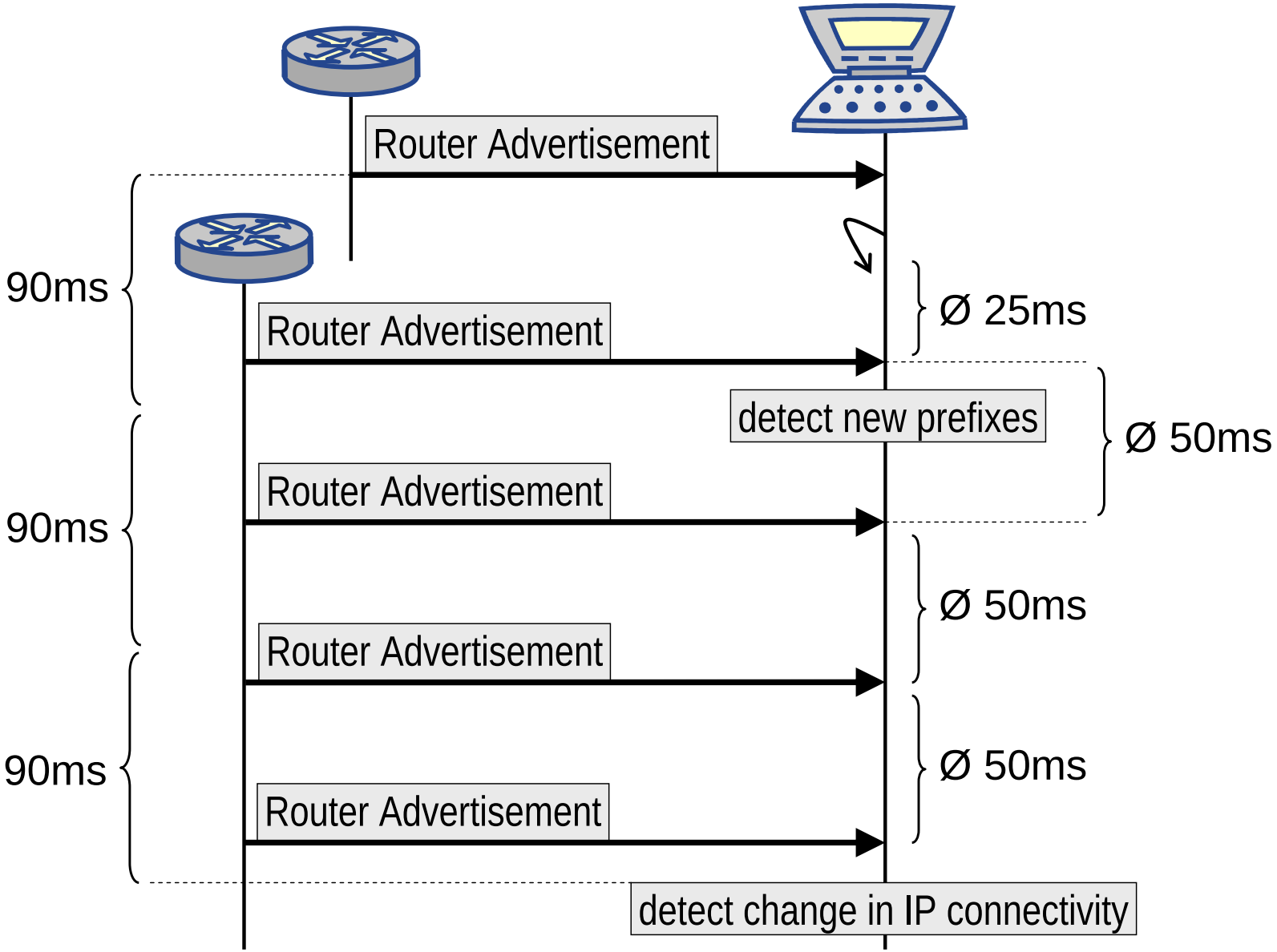
Movement Detection

- To determine changes in IP connectivity
  - Link-layer trigger necessary, but not sufficient
  - Changes in IP connectivity $\subset$ changes in link-layer attachment
- Change in IP connectivity requires…
  - Invalidation of stale global IP addresses
  - Default router change
  - Uniqueness re-verification of link-local IP address
  - Mobile IPv6 registrations
- Monitoring of on-link prefixes
  - Prefix sets of different links disjoint
    - Old prefixes no longer seen, but new instead $\Rightarrow$ IP link change likely
    - Link-layer trigger, but same prefixes $\Rightarrow$ no IP link change

Movement Detection

- Problems
  - Different routers may advertise different prefix sets
    - Router Advertisements from 1 on-link router insufficient
  - Router Advertisements may contain incomplete prefix sets
    - 1 Router Advertisement from each on-link router insufficient
  - Packet loss
    - 1 missing Router Advertisement insufficient
  - Interval between Router Advertisements unknown
- Partial solution: Advertisement Interval option for Router Advertisements (RFC 3775)
  - Indicates upper interval bound
    - Old default router unreachable when 3 Router Advertisement missed
  - 20ms increment if interval < 200ms
    - To account for scheduling granularities
    - Configured interval 30ms~70ms ⇒ advertised interval 90ms

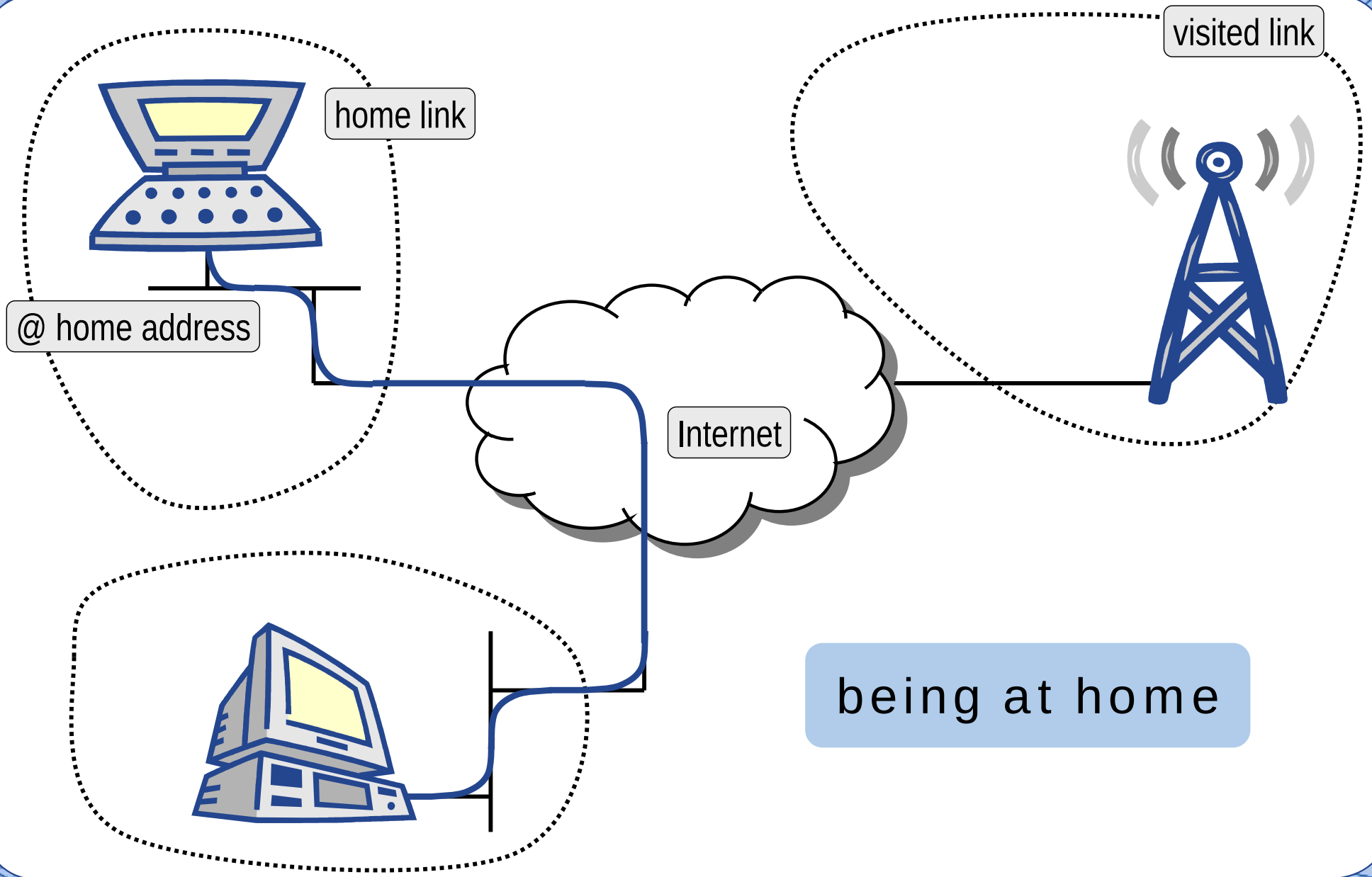
Movement Detection



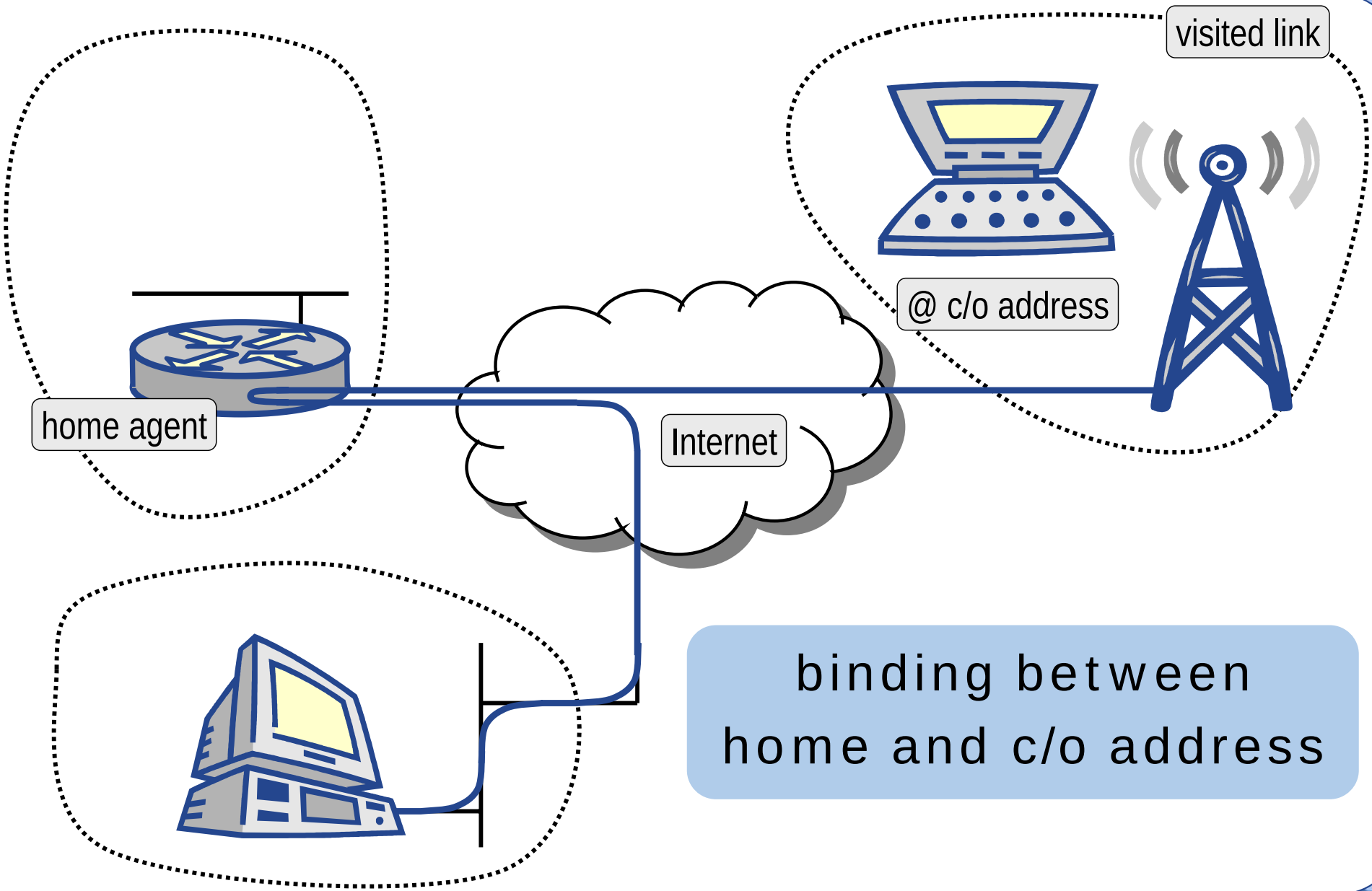
Mobile IPv6

- To resume active communication sessions after IP address change
- To maintain reachability for inbound session requests

Mobile IPv6

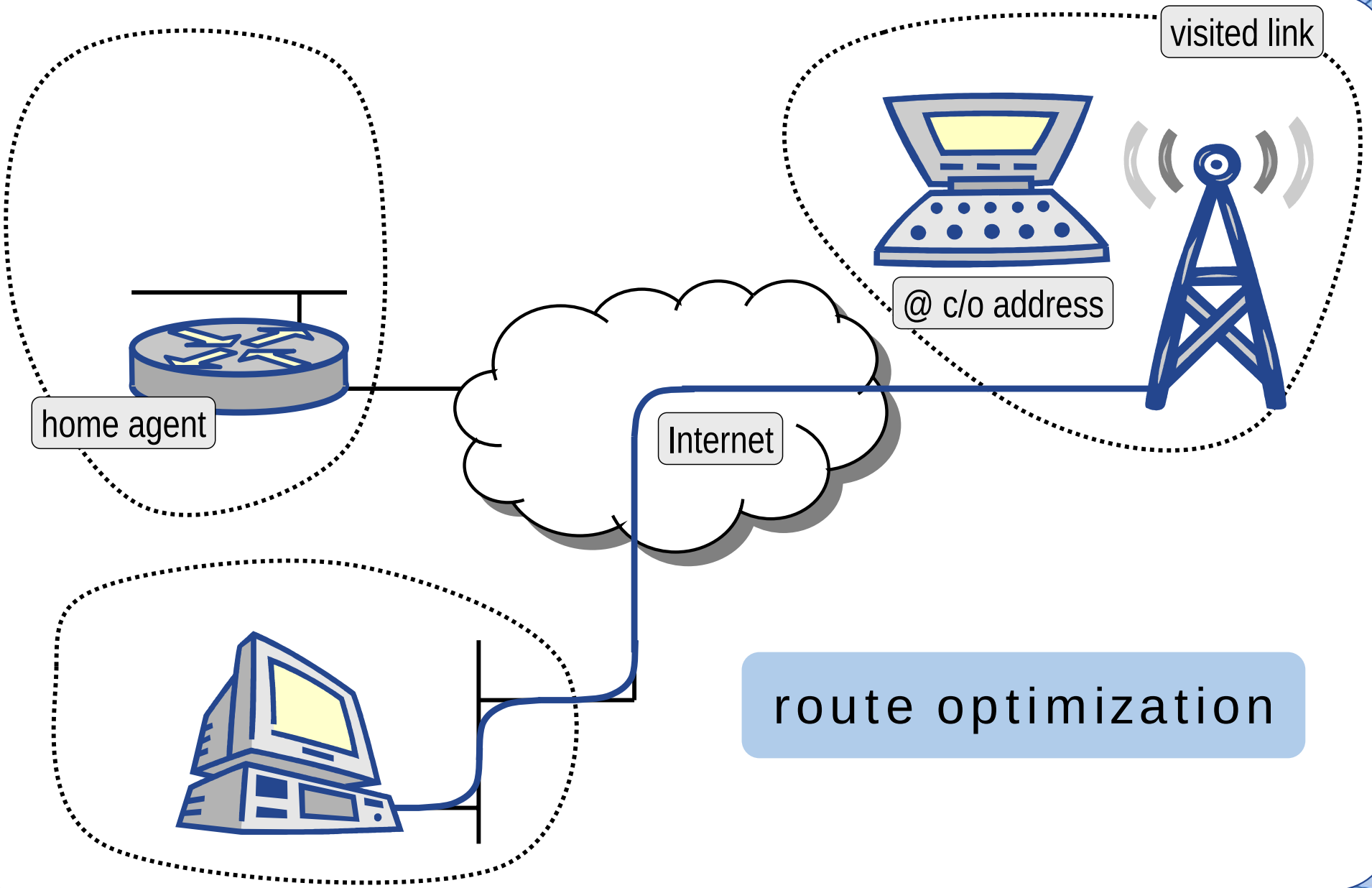


Mobile IPv6



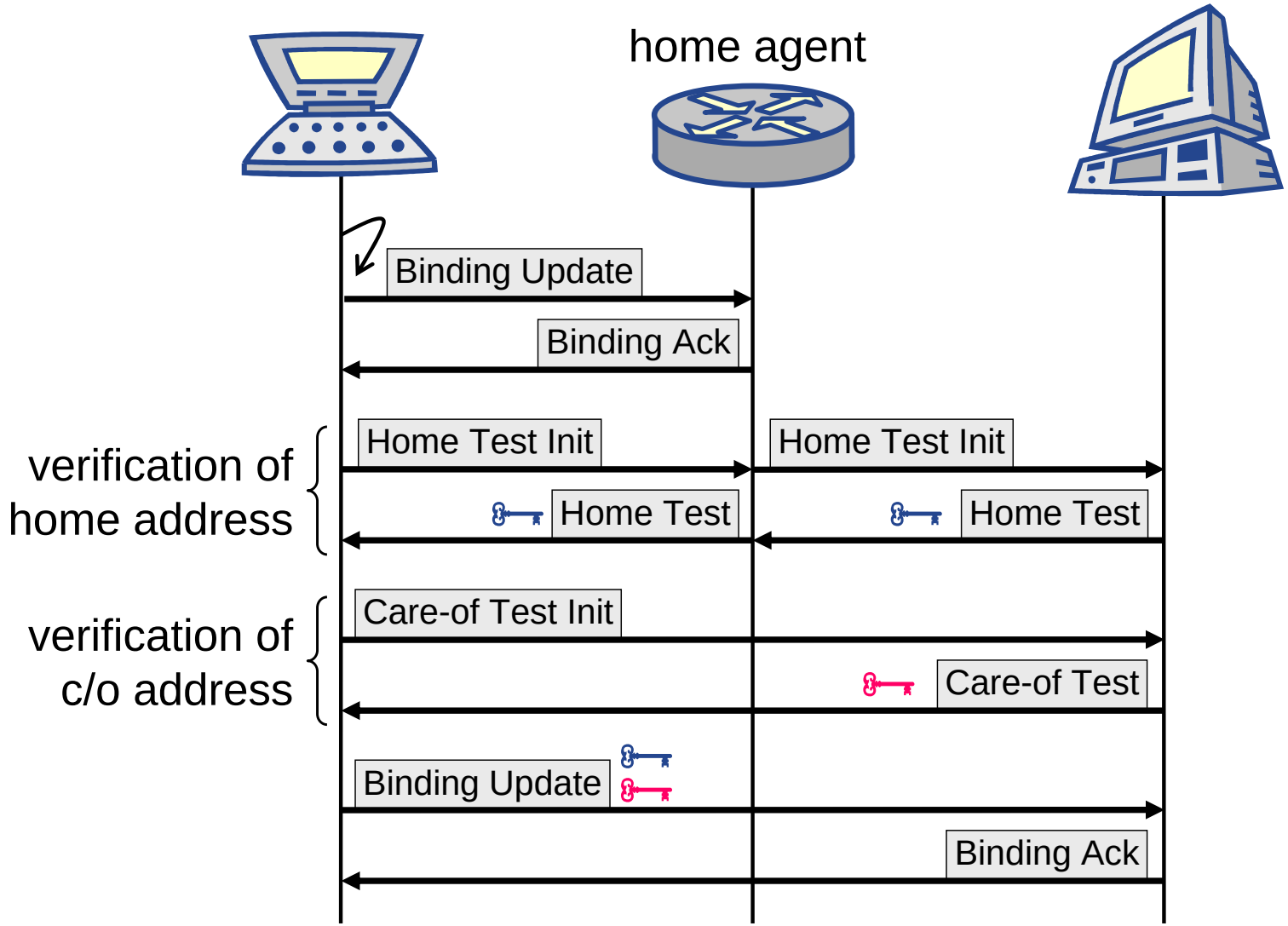
binding between
home and c/o address

Mobile IPv6

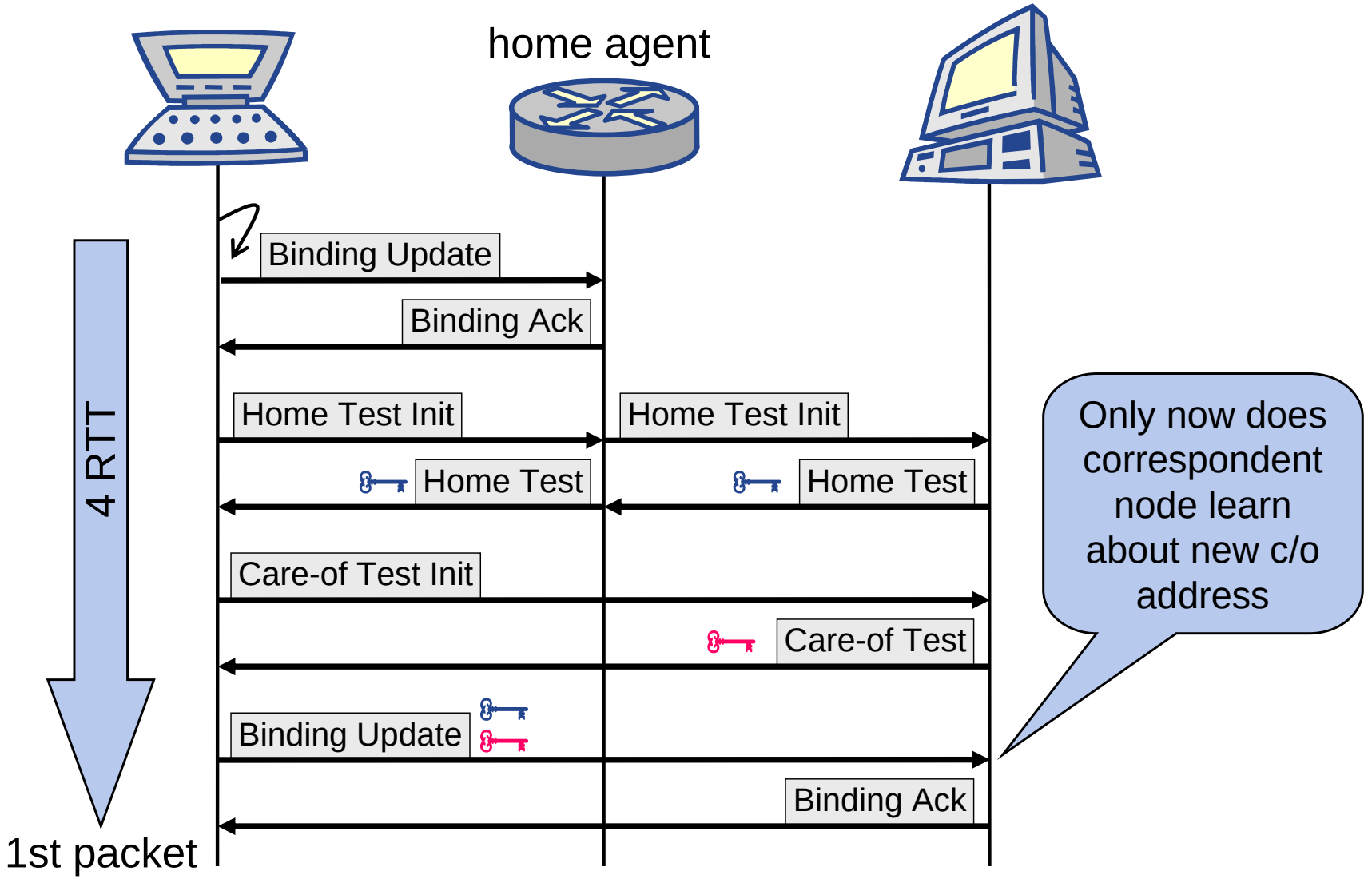


route optimization

Mobile IPv6

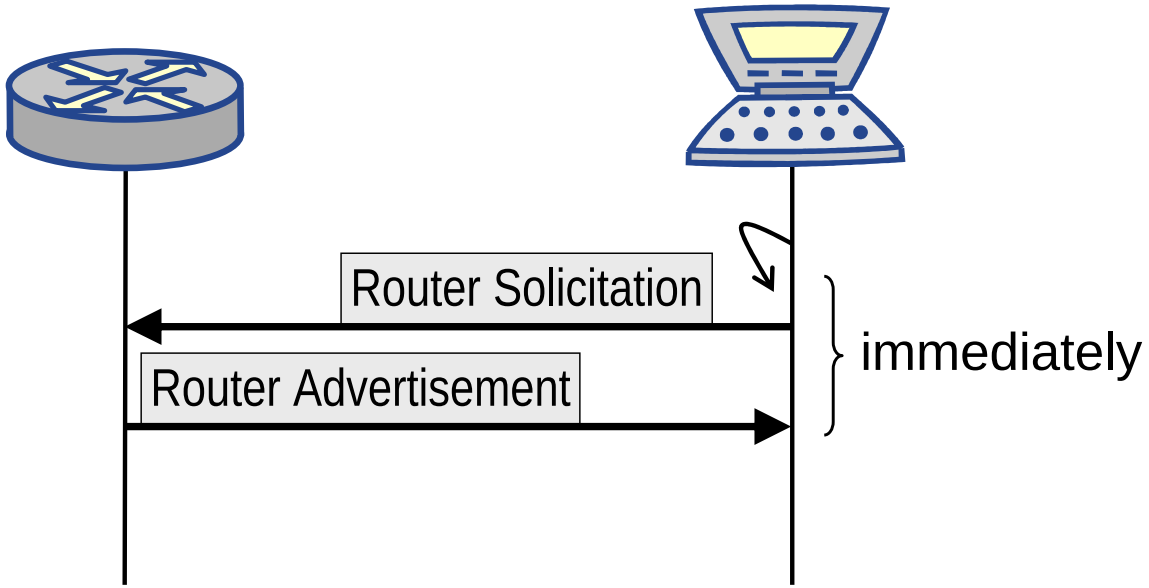

home agent
Binding Update
Binding Ack
verification of home address
Home Test Init
Home Test Init
Home Test
Home Test
verification of c/o address
Care-of Test Init
Care-of Test
Binding Update
Binding Ack

Mobile IPv6


home agent
Binding Update
Binding Ack
Home Test Init
Home Test Init
Home Test
Home Test
4 RTT
Care-of Test Init
Care-of Test
Binding Update
Binding Ack
1st packet
Only now does correspondent node learn about new c/o address

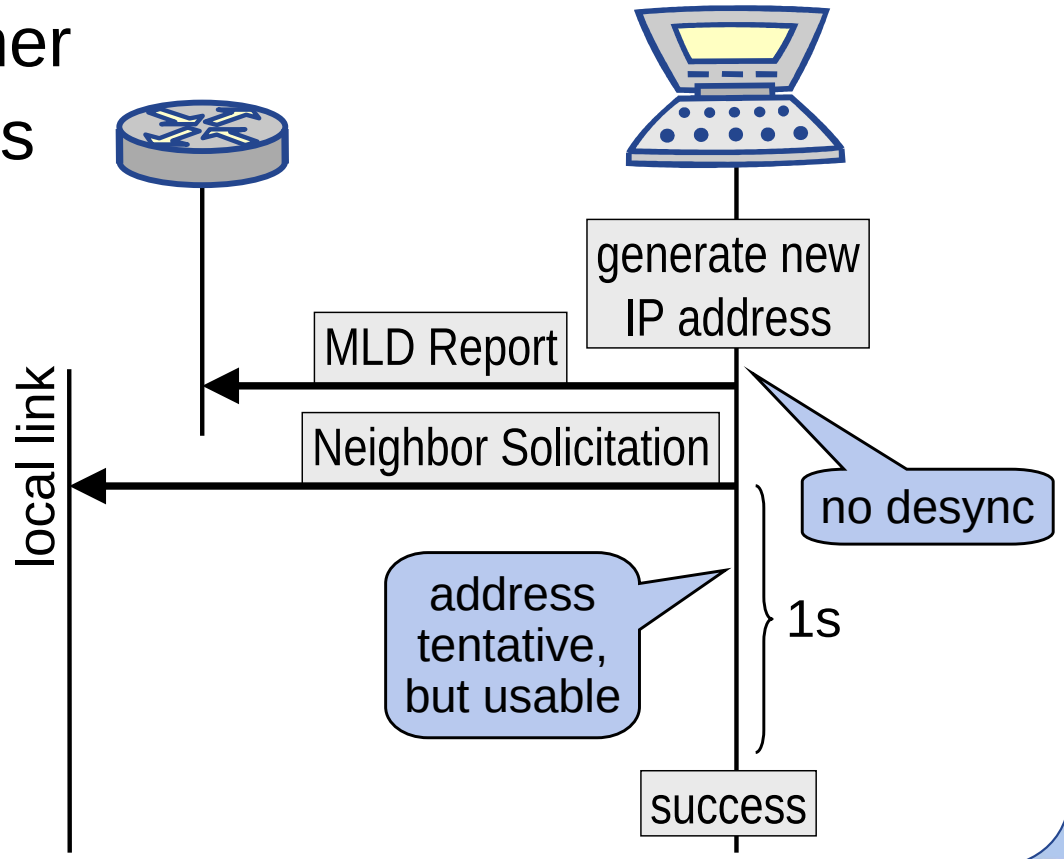
Related Work

- FastRA improves router discovery
  - Node solicits immediate Router Advertisement
  - Distributed algorithm defines order in which to respond



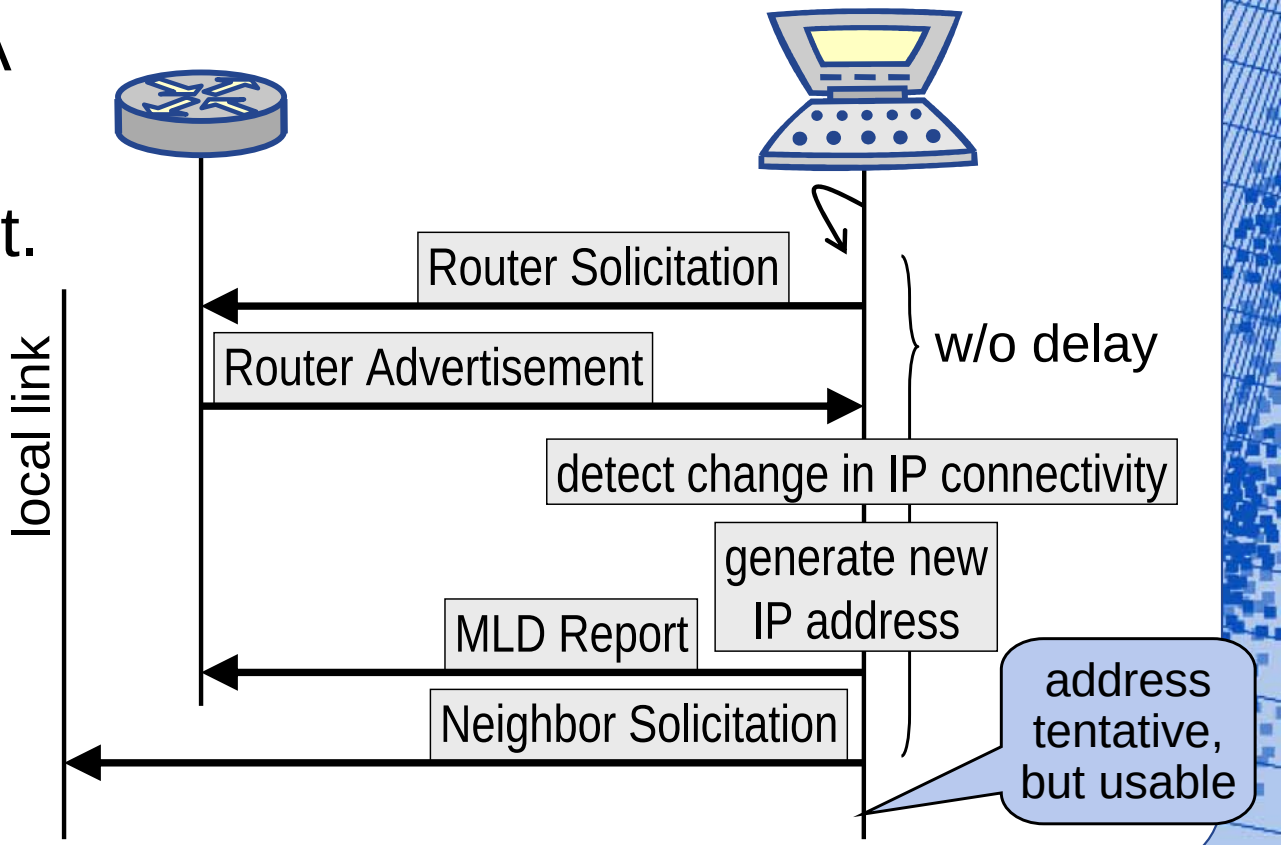
Related Work

- Optimistic Duplicate Address Detection improves address configuration
  - Node may use new IP address during verification,…
  - but may not disrupt other nodes' neighbor caches



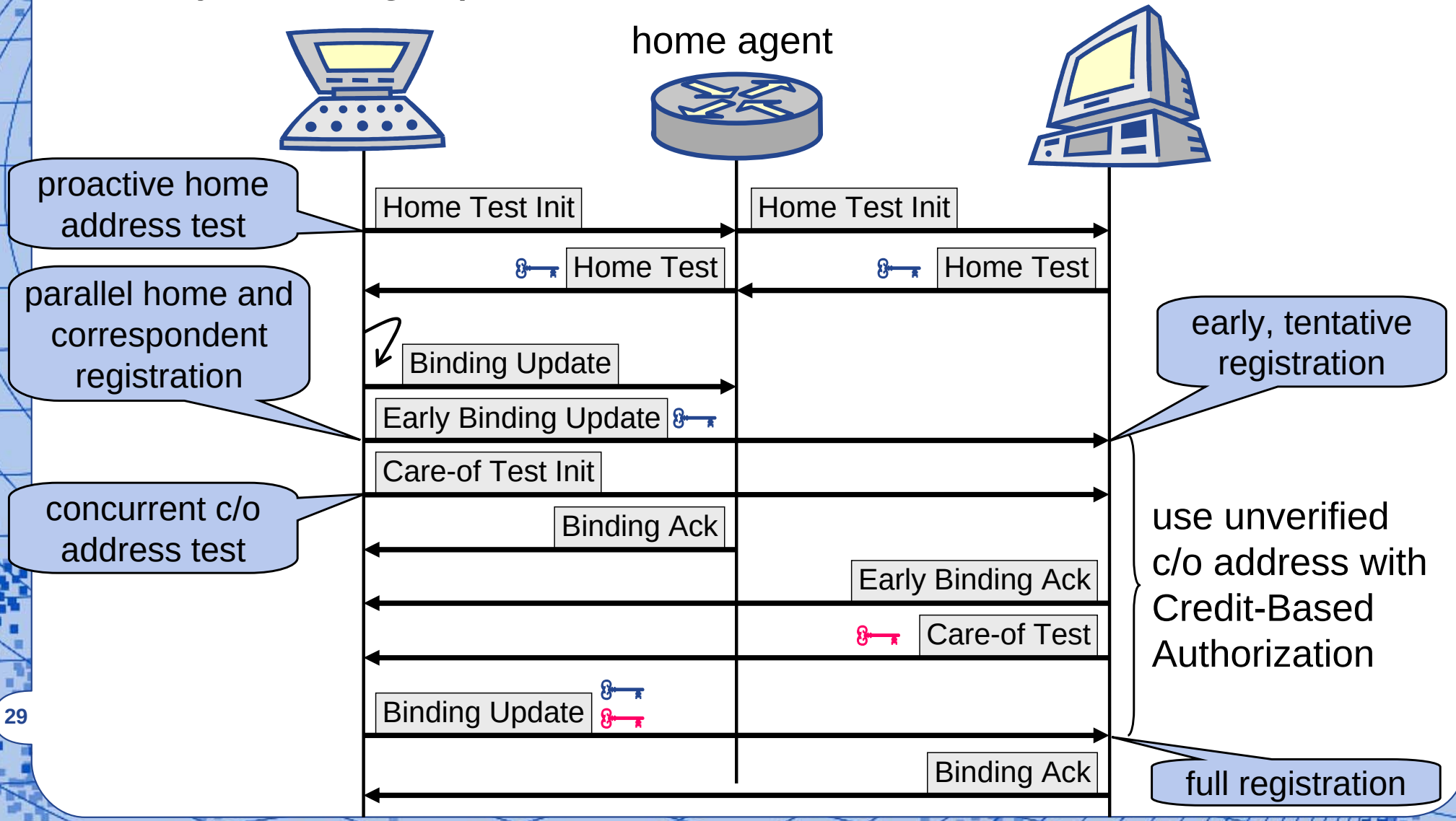
Related Work (More in the Paper…)

- DNA protocol improves movement detection
  - Link identifiers, landmarks ease movement detection
  - 1 Router Advertisement enough to detect link change
  - Integrates FastRA and Optimistic Dupl. Addr. Detect.



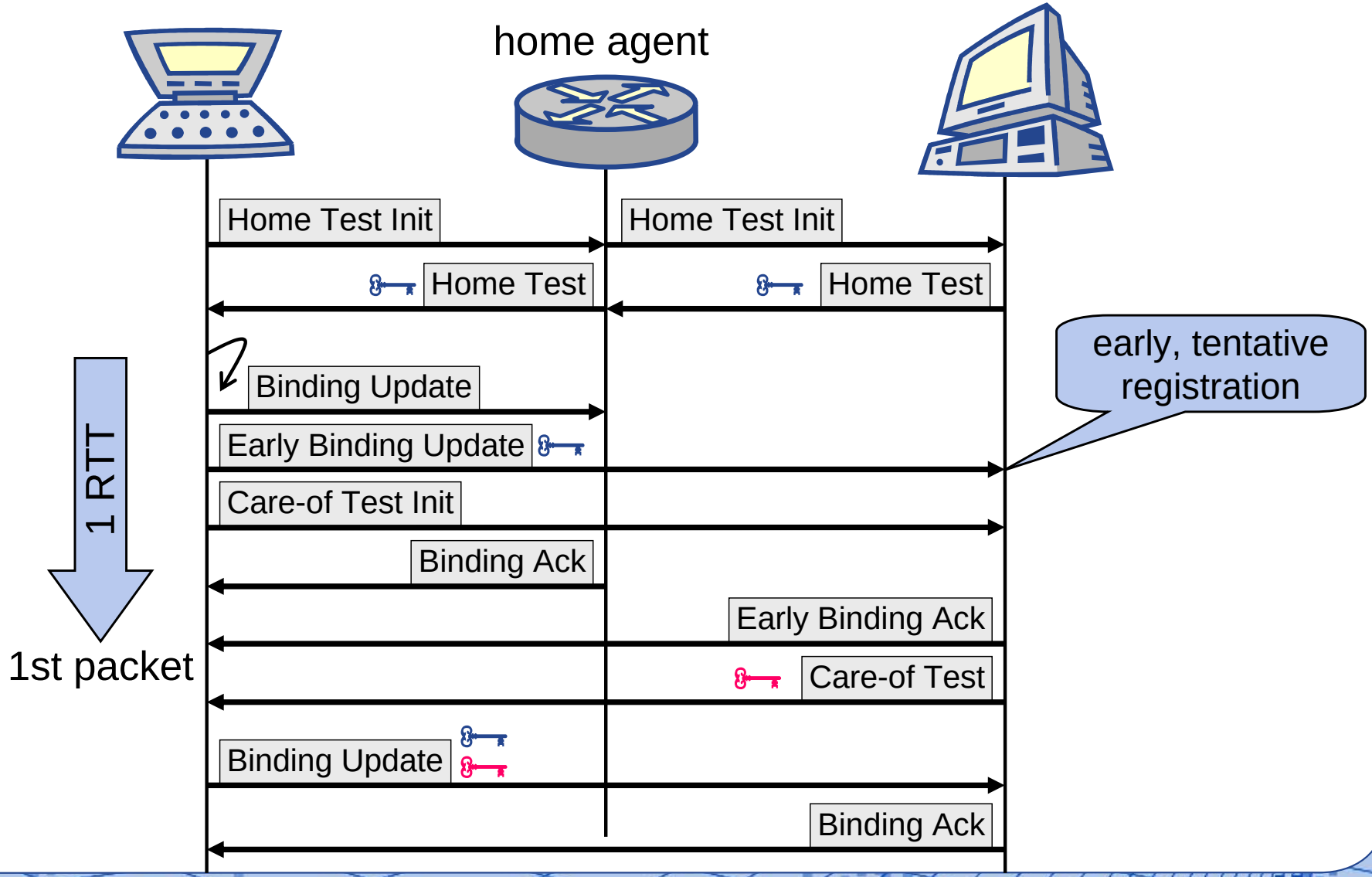
Proposed Mobile IPv6 Optimizations

- Early Binding Updates, Credit-Based Authorization

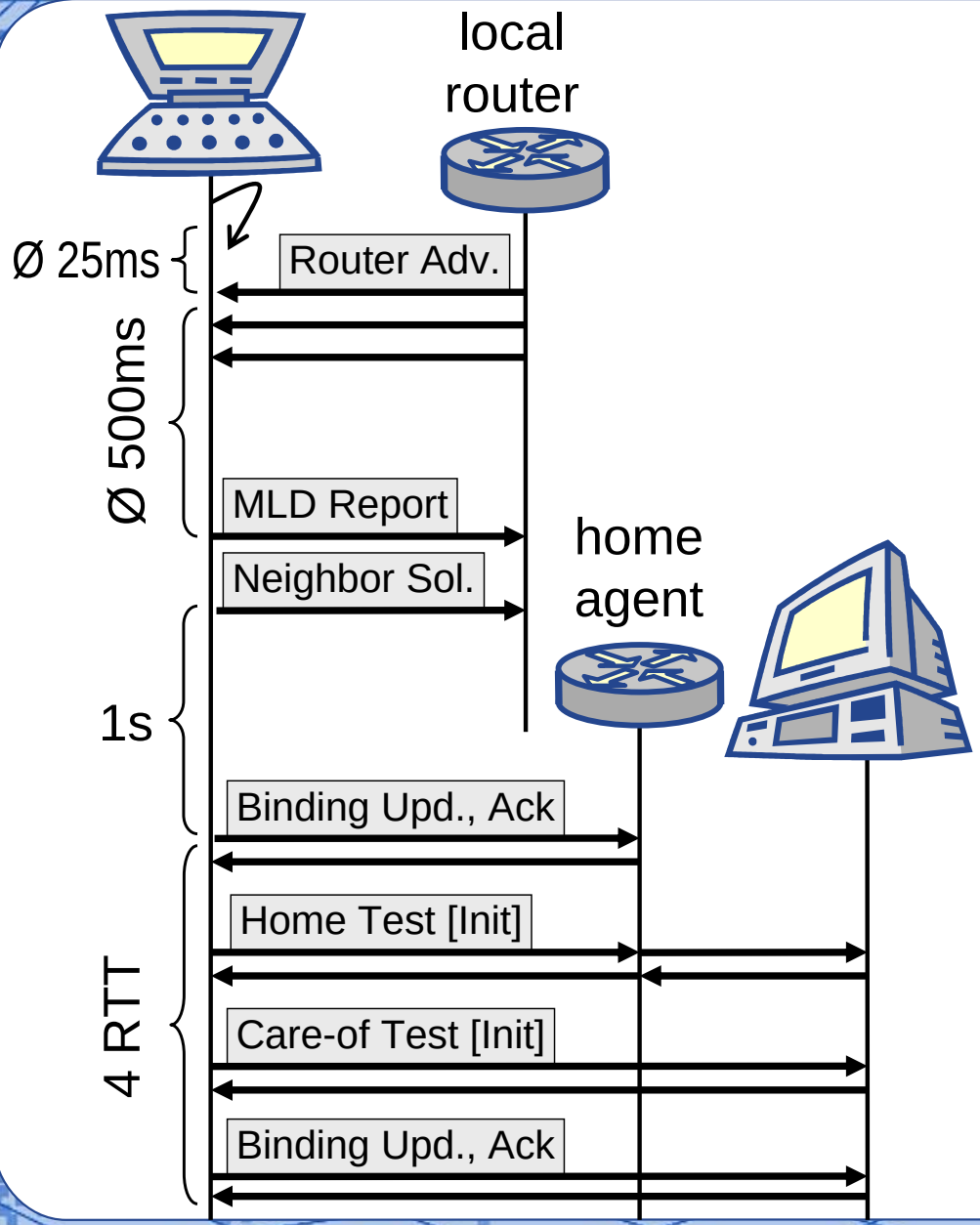


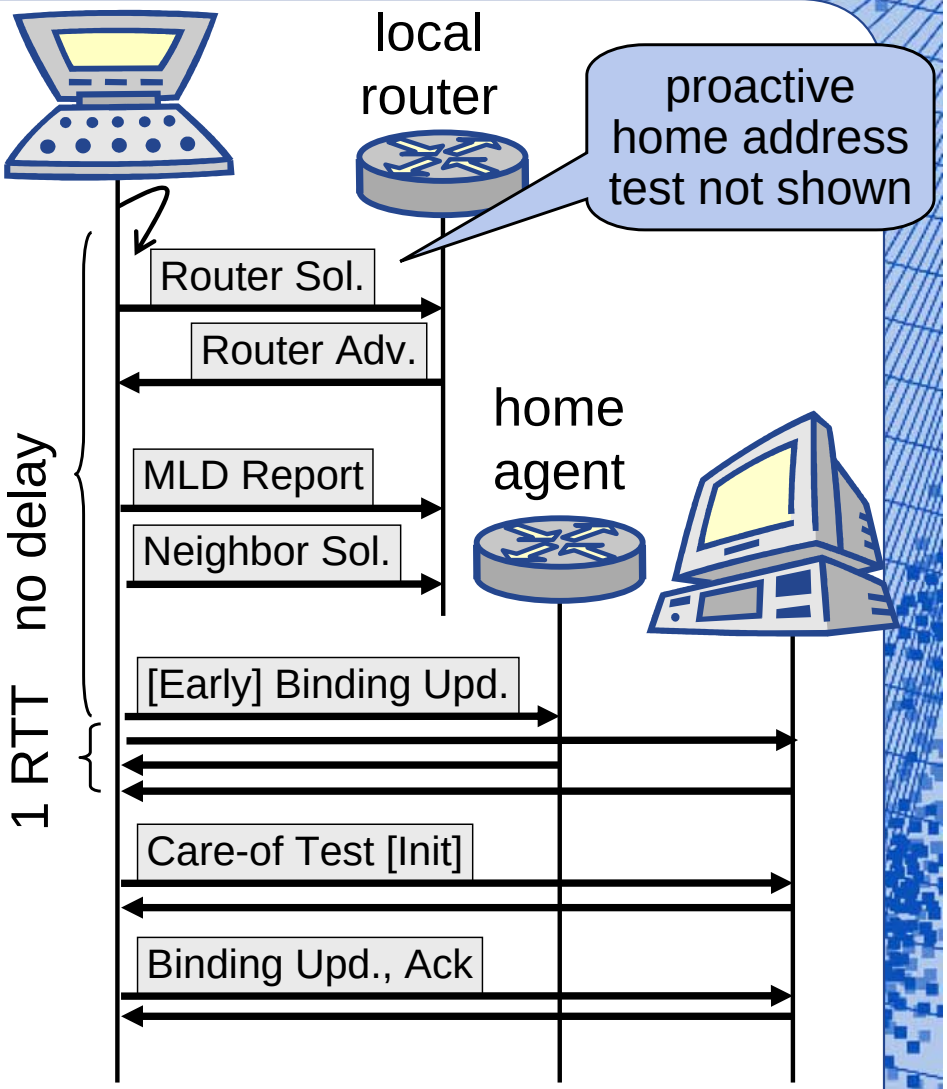
Proposed Mobile IPv6 Optimizations

- Early Binding Updates, Credit-Based Authorization



Comparison of Handoff Procedures





Conclusions and Future Work

- Handoff delays for standard auto-configuration substantial
  - Delays due to conservative advertisement frequencies, desynchronization, and duplicate address detection
  - Optimizations have enormous impact
    - Eliminate desynchronization delays
    - Use tentative IP addresses during duplicate address detection
    - More informative Router Advertisements to ease movement detection
    - Apply proactivity, concurrency, and parallelism in Mobile IPv6
- Mobility protocol optimizations only useful in conjunction with auto-configuration optimizations
- Future work on proactive handoff management