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Earth with 2 Billion Mobile devices

- One billion is a large number; we'll be there this year or next
- It's never been done before!
- In the beginning, most of them will not be Internet enabled, but they will come online rapidly
- If IPv4 can do it at all, it will be at a tremendous (unimaginable, even) cost in complexity
- Only IPv6 offers enough addresses; the Internet is still young!
- IPv6 also offers the features needed for mobile networking
- Only Mobile IPv6 takes advantage of the IPv6 features to offer seamless roaming
- Network layer roaming also enables significant cost reductions and improved deployability
Why Mobile IP?

- Both ends of a TCP session (connection) need to keep the same IP address for the life of the session.
  - This is the home address, used for end-to-end communication.
- IP needs to change the IP address when a network node moves to a new place in the network.
  - This is the care-of address, used for routing.

Mobile IP considers the mobility problem as a routing problem:
- Managing a binding, i.e., a dynamic tunnel between a care-of address and a home address.
- Of course, there is a lot more to it than that!

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Mobile IP protocol overview

- Routing Prefix from local Router Advertisement.
- Seamless Roaming: Mobile Node appears “always on” home network.
- Address autoconfiguration $\rightarrow$ care-of address.
- Binding Update $\rightarrow$ home agent & correspondent nodes.
  - (home address, care-of address, binding lifetime)

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IPv6 features used for Mobile IPv6

- Enough Addresses.
- Enough Security (we thought).
- Address Autoconfiguration for getting care-of addresses.
- Destination Options (and, now, Mobility) extension headers.
- Also, reduced Soft-State, etc., not covered here.
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Features added for Mobile IPv6

- Binding Cache management in new Mobility Header
  - a lot like the existing Destination Options header
- Route optimization using new Route Header
  - But, it's almost exactly like the existing one
- New ICMP messages
  - For Home Agent discovery
- New Router Advertisement extension
  - For renumbering
  - Binding Request message type

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Enough Addresses

- 340 undecillion addresses
  - \[340,282,366,920,938,463,463,374,607,431,768,211,456\] total!
- Needed for billions of IP-addressable wireless handsets over the next 20 years
- IPv4 address space crunch driving current deployment of NAT
  - But, multi-level NAT unknown/unavailable
  - Besides, NAT not useful for always on operation
- Even more IP addresses needed for embedded wireless!
- Especially interesting for Asia now
  - China has 22 million IPv4 addresses and 130+ million handsets

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Security issues: (almost sufficient)

- Authentication Header mandatory to implement
- Encapsulating Security Payload mandatory to implement
- Needed for Binding Update
  - Remote Redirect problem
- Key distribution still poorly understood
  - PKI?
  - AAAv6 w/ symmetric key?
- Can your m-commerce server manage 10 million security associations?
- Can your light bulb manage 10 security associations?
- "First, do no harm"
**Route Optimization**

- Most Internet devices will be mobile, so we should design for that case for the health of the future Internet
- Binding Update SHOULD be part of every IPv6 node implementation, according to IETF specification
- Reduces network load by ~50% (depending on your favorite traffic model)
- Route Optimization could double Internet performance
  - reduced latency
  - better bandwidth utilization
  - reduced vulnerability to network partition
  - eliminate any potential Home Agent bottleneck

**Message Types**

- Binding Cache Maintenance
- Binding Update
- Binding Acknowledgement
- Binding Request
- Home Address Option
- Return Routability Tests
  - Home Address Test Initiate
  - Care-of Address Test Initiate
  - Home Address Test
  - Care-of Address Test
- Renumbering Messages
  - Mobile Prefix Solicitation
  - Mobile Prefix Advertisement
- Home Agent Discovery

**Ingress Filtering and Home Address Option**

- Ingress filtering border routers enforce topologically correct source IP address fields
- End-to-end applications want to deal with home address exclusively
- Topological correctness requires the care-of address to be in the Source IP address field
- IP traditionally passes the Source IP address field up to higher level protocol (e.g., TCP)
- Home Address Option changes this behavior, so that the option data is passed instead (i.e., the home address?)
- Result: topological correctness AND stable identification for higher-level protocols
Establishing a Binding Security Association

- BSA is needed specifically for authenticating Binding Updates
- Return Routability (RR) tests rely on routing infrastructure
- Mobile IPv6 RR enables mobile authentication, not identification
  - Latter could require validation via certificate authority
  - The correspondent node only has assurance that the Binding Update comes from the same node as before
- Mobile IPv6 solution resists Denial of Service (DoS) attacks
  - "First, do no harm"
  - That is, we must be as safe as communications between statically located IPv4 network nodes
- Only nodes between correspondent node and home network can disrupt traffic

RR Protocol Overview

- Test return routability for home address (HoTI, HoT)
- Test return routability for care-of address (CoTI, CoT)
- HoT and CoT carry nonces to be combined to make Kbu
- Very few nodes see nonces in both HoT and CoT
- BSA in current specification is short-lived
- Correspondent node keeps no per-mobile state during HoT/CoT
- Diffie-Hellman could be another option
  - but it’s either expensive or patented

Home Address Test Initiate (HoTI)

- Mobility Header message type 1
- Contains 32-bit mobile cookie
- Can contain a Unique Identifier option
- Cannot contain a Home Address destination option
- Source IP address is the mobile node’s claimed Home Address
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**Care-of Address Test Initiate (CoTI)**
- Mobility Header message type 2
- Contains (possibly different) 32-bit mobile cookie
- Can contain a Unique Identifier option
- Source IP address is the mobile node's claimed Care-of Address
- HoTI/CoTI expected to be sent at about the same time, but after sending the Binding Update to the Home Agent

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**Home Address Test (HoT) message**
- Nonce Index to be used in Nonce Indices option to Binding Update
- Mobile Cookie copied from Home Address Test Initiate message
- Home Cookie used as input for creating security association
- Type 3 message using Mobility Header

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**Care-of Address Test (CoT) message**
- Nonce Index also to be used in Nonce Indices option to Binding Update
- Mobile Cookie copied from Care-of Address Test Initiate message
- Care-of Cookie also used as input for creating security association
- Type 4 message using Mobility Header
- When mobile node receives HoT and CoT, it can then send the Binding Update to the correspondent node
Mobile IPv6 status

- Mobile IPv6 testing event Sept 15-17, 1999
- Bull, Ericsson, NOKIA, INRIA
- ETSI bake-offs, 2000 & 2001 - success!
- Connectathon March 2001, 2002 - success!
- Return Routability for Key Establishment
- Distinguishing between renumbering and movement
- tunneled router solicitations and advertisements
- Authentication data in option, as well as in AH or ESP (?)
- Fast handover design team has issued Internet Draft
- Chairs and ADs are pushing for re-completion
  - Draft ... -17.txt issued last week, may go to Last Call
  - Draft ... -18.txt likely to be needed early June

Challenges for Mobile IPv6

- Achieving Proposed Standard (esp. re: HAO)
- Legacy equipment and smooth transition (esp. with HLR)
- Walled Gardens (mobile access to all Internet services desired)
- Application adaptations to mobility (new APIs needed)
- Security protocol development, deployment (key distribution)
- Maintaining same level of quality as in current cellular (help here [试addr])
- Enabling ad hoc networking (what is the business model?)
- Governmental considerations (location)
- Harmonizing 3GPP and 3GPP2
- Video?
- IPQoS
- Social awareness to restore the end-to-end application model (vs., e.g., NATs)
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Summary and Conclusions

- Mobile IPv6 offers scalable, secure, and high-performance mobility management
- Mobile IPv6 is working, and new issues are resolved
  - There's lots of interoperability experience, but new draft is different
  - Implementation is natural under IPv6 and IPsec
- Binding update now has a lightweight key establishment protocol
  - “First, do no harm”