IPv6, IETF, and Mobile Networking

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Outline of Presentation

- IPv4 address space exhaustion
- IPv6 in General
- IETF and relevant working groups
- Mobile IPv6
- Ad Hoc Networking
Earth with Billions of Mobiles

- One billion is a large number, but we are way past that
- We are navigating uncharted waters
- In the beginning, most phones weren’t Internet enabled, but they are coming online rapidly
- IPv4 can do it but at a tremendous cost in complexity
- Only IPv6 offers enough addresses; Internet is young!
- IPv6 offers features needed for mobile networking
  - Mobile IPv6 takes advantage of them to offer seamless mobility.
- Network-layer mobility could enable significant cost reductions and improved deployability
High probability that IPv4 addresses will be exhausted by the end of the decade.
IANA Allocations to RIRs

Allocations per year

Cumulative allocations

6 months
IPv6: It’s not rocket science

<table>
<thead>
<tr>
<th>Ver.</th>
<th>Traffic Class</th>
<th>Flow Label</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Payload Length</td>
<td>Next Header</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hop Limit</td>
</tr>
</tbody>
</table>

Source Address

Destination Address

<table>
<thead>
<tr>
<th>Ver.</th>
<th>Hdr Len</th>
<th>Type of Service</th>
<th>Total Length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Identification</td>
<td>Flg</td>
<td>Fragment Offset</td>
</tr>
<tr>
<td></td>
<td>Time to Live</td>
<td>Protocol</td>
<td>Header Checksum</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Source Address</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Destination Address</td>
</tr>
</tbody>
</table>

Options...

shaded fields have no equivalent in the other version

IPv6 header is twice as long (40 bytes) as IPv4 header without options (20 bytes)
Enough Addresses

- 340 undecillion addresses
  - \((340,282,366,920,938,463,463,374,607,431,768,211,456)\) total!
- We’ll have perhaps tens of billions of IP-addressable wireless handsets and devices over the next 20 years
  - Even more IP addresses needed for embedded wireless!
- IPv4 address space crunch driving current deployment of NAT
  - NAT makes *always on* operation (e.g., VoIP) difficult
  - NAT hurts applications, and obstructs new applications
  - NAT is a serious power drain
- IPv6 especially interesting for China now
  - 22 million IPv4 addresses and 350+ million handsets
IETF mantra

*Rough consensus and running code*

- Consensus requires persistence and team-building
- Running code requires sweat and interoperability
IETF structure

IETF has Areas and Area Directors (ADs)
IETF has over 100 working groups:
• General Area (AD is IETF chair)
• Applications Area
• Internet Area (most mobility groups here)
• Operations and Management Area
• Routing Area ([manet] is here!)
• Security Area
• Transport Area
IETF Organizational structure

ISOC  IAB  IESG

Monitors Appointments  Monitors Appointments

General  Transport  Apps  Internet  Routing  O&M  Security

Charters WGs

e2e  rtg  rel. mcast

...  manet

Infocom 2006, Barcelona  April 26, 2006  Copyright 2006  Slide 10
IETF process (theoretically…)

- IESG/RFC editor delays
  - Career churn → torch passing
- Process is working poorly
- Internet runs on PS
- [newtrk] WG
v6-related IETF working groups

- ipv6
- mip6
- mipshop
- monami
- dna
- nemo
- autoconf / manet
- netimm
- 6lowpan
- shim6
- softwire
- seamoby
- send
- IR TF:
  - mobo pto ts

This is a huge amount of effort overall
IPv6 protocol documents

- RFC 1887: Address architecture
- RFC 2460: IPv6 Protocol specification
- RFC 2461: Neighbor discovery
- RFC 2462: Stateless Address Autoconfiguration
- RFC 3315, RFC 3736 - DHCPv6, Stateless DHCPv6
- RFC 2406: Encryption (privacy)
- RFC 2402: Authentication
- RFC 3775: Mobile IPv6
- RFC 3041: Randomized address configuration
- RFC 4193: Unique Local Unicast Addresses
- RFC 4213: Basic transition mechanisms
- RFC 39xx: Cryptographically Generated Addresses
- Dozens more… Plus, quite a few more almost done
Mobile IP: what is it?

• Both ends of a TCP session (connection) need to keep the same IP address for the life of the session.
  – 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.
  – The care-of address, used for routing

Mobile IP models the mobility problem as a routing problem
  – managing a binding – that is, a dynamic tunnel between a care-of address and a home address

• Of course, there is a lot more to it than that!
  – service discovery, session persistence, context xfer,…
Mobile IP protocol overview

- Routing Prefix from local Router Advertisement
- Address autoconfiguration → care-of address
- Binding Updates → home agent
  - (home address, care-of address, binding lifetime)
- *Seamless Roaming.* Mobile Node “always on” home network
- correspondent nodes → BindingUpd [“Route Optimization”]
Floor wax or ice cream dipper?

- IP address – what is it?
  - Locator?
  - Identifier?
  - For fixed nodes, it never mattered

- All mobility schemes need stable identifiers
  - NAI, HIT, DNS, TMSI, IP address, MAC addr., URI, Session ID, …
  - Distributed vs. centralized directory lookup
  - IP address seems to offer a unique advantage: the *identifier* automatically locates the *directory*
IPv6 basic features in Mobile IPv6

• Enough Addresses
• Enough Security (well, almost)
• Address Autoconfiguration: care-of addresses
• Destination Options (and, now, Mobility) extension headers
• Multicast, Anycast
• also, reduced Soft-State, MI Bs, etc.
Route Optimization

• Almost all future Internet devices to be mobile or wireless
• *SHOULD* implement Binding Update in all IPv6 nodes
• Reduces network load by \( \sim 50\% \) (depending on traffic model)
• Route Optimization “could” double Internet performance
  – reduced latency
  – better bandwidth utilization
  – reduced vulnerability to network partition
  – eliminate a potential Home Agent bottleneck
• Downside: authentication is *required* but *nontrivial*
Establishing a Binding Security Association

- BSA is needed for authenticating Binding Updates
- “First, do no harm”
  - As safe as communications of motionless IPv4 nodes
  - Only nodes between correspondent node and home network can disrupt traffic
- Return Routability (RR) relies on routing infrastructure
- Mobile IPv6 RR enables authentication, not identification
  - Latter could require validation via certificate authority
  - Correspondent node only if it is the same node as before
- RR solution resists Denial of Service (DoS) attacks
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 $K_{bu}$
- 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
Ad Hoc Network characteristics

- peer-to-peer
- multihop
- dynamic
- *Really* “anytime, anywhere”
- zero-administration
- low power
- autonomous
- autoconfigured

But, most of these have exceptions!
Ad Hoc nodes & IPv6 addressability

- IPv6 offers enough addresses for the coming billions of wireless devices
- Ad hoc devices need zero-administration
- NAT boxes are notorious power drains
- IPv4 address autoconfiguration approaches are not at all trivial
- Ad hoc devices need reduced signaling
- IPv6 reduces or even eliminates complexity
Assured Address Uniqueness

• IPv6 => probable address uniqueness!
  – By construction from MAC address
  – By random selection
  – Optimistic DAD, e.g.

• This eliminates complexity and signaling

• Even more important for wireless
  – And even more so for sensor nets!
  – Better energy use: 1 bit = 10,000+ CPU cycles
Ad Hoc Routing Projects

- Terminodes (EPFL)
- WINGs (JJ Garcia/UCSC)
- ROAM (JJ Garcia/UCSC)
- WAMIS (Gerla/UCLA)
- ODMRP (S.J. Lee/UCLA)
- TRAVLR (Kleinrock)
- Tora/IMEP (Park/UMD)
- Link Quality (Dube/UMD)
- LAR (Texas A&M)
- TBRPF/PacketHop (SRI)
- OLSR (Clausen/Jacquet)
- DSDV (Dest. Sequence #'s)

- AODV (refinement of DSDV)
- AOMDV (Multipath/Das et al.)
- LANMAR (Gerla et.al/UCLA)
- GPSR (Karp/Harvard)
- CBRP (Singapore)
- DSR (Dave Johnson, CMU)
- MMWN (Steenstrup/BBN)
- ABR (C.K. Toh)
- STAR (JJ Garcia/UCSC)
- ZRP (Zygmunt Haas/Cornell)
- Fisheye/Hierarchical (UCLA)
- CEDAR (Urbana-Champaign)
More Ad Hoc Routing Projects

- FRESH (latest encounter)
- ANTS (swarm intelligence)
- Ariadne
- Cryptographic Threshold
- Insignia [QoS] (Columbia)
- AODV6
- FLR [“Feasible”] (UCSC)
- GPS/Geographic
- SHARP
- DMAC (Directional)
- Pulse
- TDR (Trigger based Distributive)
- DREAM
- SAODV (Guerrera)
- LDR (Mosko/Garcia …/Perkins)
- AODVjr (Chakeres/Klein-Berndt)
- WRP
- Minimum-energy approaches
- Compow
- Face Routing (GOAFR+,…)
- XTC (Topology Control)
- *Many more…*
Mobile Ad Hoc Networking (manet)

- AODV: on-demand, and distance-vector
  - Interoperability testing
  - Experimental RFC 3561
- Other on-demand protocol is (DSR)
- Two link-state, table-driven / proactive protocols
  - RFC 3626: Optimized Link-State Routing (OLSR)
  - RFC 3684: Topology-Based Reverse Path Forwarding (TBRPF)
- DSR should also be published as Experimental
- Many other protocols have been considered!
  - For instance, quite a few of the previous list
Address assignment, as needed
  - Disconnected/isolated network case
  - Connected to Internet via a gateway
Gateway provides routable address prefix
  - Allows packets to reach manet nodes
Nodes can use permanent address with new care-of address in manet
Ad Hoc Stub Networks

• If any node has access to the Internet, then all nodes can have access.
Strategies for address allocation

- Random (works well with IPv6)
- Constructed from MAC address (also works well with IPv6)
- Address pool/subdivision (likewise!)
- Problem: network partition/remerge
Summary

- **IPv6 enables stable, long-term addressability**
  - This is important for identifiers, thus for mobility
  - Even more so for ad hoc nodes needing to obtain addresses

- **IPv6 is ready to roll out now**

- **We “have to” do it eventually anyway**
  - Maybe the users (the real Internet) will never know
  - But people are still driving Hummers, oops, oh well…

- **Mobile IPv6 offers scalable new authentication**
  - Revolutionary? Can we derive further benefits?

- **NATs deterioriate wireless nodes and services**
  - NATs damage the ability to have stable addresses
  - Ad hoc *unworkable* with overlapping IP addresses