Introduction to the IETF’s Routing Area

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What We Want to Tell You

• We want to give you an overview of the breadth of work covered in the Routing Area
• We want to show how the work is divided between...
  – Support of core protocols without which the Internet would not operate
  – Applications of those protocols,
  – Specialist routing protocols for niche environments
  – Experimentation in new routing technologies
• We will do this by walking you through the list of working groups in the area
What We’re Not Going to Tell You

• This is not a presentation about how routing works
• And it is not a discussion about how to design a routing protocol
• We have no plans to tell you whether OSPF is better or worse than IS-IS
History

• Routing has been recognized as a core division of the IETF’s work from the beginning
  – In 1989 there were just 6 ADs
    • OSI co-existence (x2)
    • Internet Services
    • Network Management
    • Routing
    • Host-Based
Some Numbers

• IETF has seven Areas
  – ART, GEN, INT, OPS, RTG, SEC, TSV (14%)
• IETF has 15 Area Directors
  – 3, 1, 2, 2, 3, 2, 2 (20%)
  – Some ADs take responsibility for WGs in other Areas
• IETF has 134 working groups
  – 42, 1, 20, 15, 23, 18, 15 (17%)
• IETF published 260 RFCs in year to June 30, 2015 [1]
  – {6+29+23}, 33, 32, 71, 21, 20 (27%) [2]

[2] The ART Area is formed from the previous APP and RAI Areas
What is Routing?

- Hosts are not all directly connected to each other
- This means (IP) packets must be forwarded hop-by-hop across the Internet
- Routers receive packets on one interface and decide which interface to forward them out of
  - This is routing; the path followed by a packet is a route
- Routes are either known in a distributed fashion
  - Each router determines the next hop towards a destination from information about the network and an algorithm
- Or they are known in a programmed way
  - The whole route is pre-determined
- Routing protocols distribute information about the network or about pre-determined routes
- The Routing Area concerns itself with protocols and mechanisms to route packets, and with uses of those protocols
When is Routing Not Routing?

• There are problems in the IETF that are very similar to classic routing problems
  – Finding paths across a graph to deliver data
  – But they are not about delivering or routing packets
• These are largely in the APP Area
  – Content Delivery Networks Interconnection (CDNI)
  – INtermediary-safe SIP session ID (INSIPID)
  – Peer-to-Peer Session Initiation Protocol (P2PSIP)
  – Session Initiation Protocol Core (SIPCORE)
• Also the SEC and TSV Areas
  – Application Bridging for Federated Access Beyond web (ABFAB – SEC)
  – Application-Layer Traffic Optimization (ALTO – TSV)
  – Multipath TCP (MPTCP – TSV)
• RTG Area is largely not involved in this work
  – May do some informal review
  – Can give advice:
    • “problems already solved”
    • “things that may bite you later”
Why is the Routing Area so Hard to Schedule?

• There is a strong inter-relationship between many of the RTG WGs
  – Many routing technologies build on core routing protocols
  – Many routing protocols are complementary and need to work together
  – Some routing protocols address the same problem spaces
  – There is a relatively small core set of “routing experts”
  – There are 23 working groups, a few of which ask for more than one meeting session
  – There are usually only 17 meeting slots

• Means that some meetings “conflict”
  – You have to choose where to go
The Nature of Routing Working Groups

• Two broad categories
  – Maintenance mode
    • Old WGs for long-established protocols
    • Usually plenty of new extensions, clarifications, bug-fixes
    • No indication that these will ever close!
  – New work
    • New ideas for specialist protocols or routing applications
    • Should be more “normal” as working groups
      – Deliver on charter and close down
Sub-Divisions in the Routing Area

• Core Routing Protocols
• Specialist Routing Protocols
• Sub-IP
• Routing Support and Operation
• Routing Services
• Experiments
• Closed but not forgotten!
Core Routing Protocols

- These are the protocols that are fundamental to how the Internet works today
- The working groups are all in “maintenance mode”
  - This does not mean that there is no new work
  - It does mean that the protocols are well-established and widely deployed
- New work is treated with a high degree of caution
  - We really do not want to break the Internet
OSPF
Open Shortest Path First IGP

• One of the two shortest path first (SPF) interior gateway protocols (IGPs) in wide use
• Work is on maintenance of OSPFv2 (for IPv4)
• Focus is moving to OSPFv3 (for IPv6 and IPv4)
• Extensions for a wide range of features
  – More routing metrics
  – Better scaling
  – More link/node characteristics
  – Support for other working groups (MPLS, CCAMP, SPRING)
ISIS
IS-IS for IP Internets

• Intermediate System to Intermediate System is an old ISO routing protocol
  – The IETF took over the specification of IS-IS for IP and published RFC 1195

• Much of the work mirrors that done in OSPF
  – Except that a new version was not needed to support IPv6
  – Extensions are also made for the same features and purposes
    • Sometimes sooner and sometimes later than for OSPF
**IDR**

Inter-Domain Routing

- The Border Gateway Protocol (BGP) is sometimes described as the glue that holds the internet together
  - The WG is probably the most conservative of all IETF WGs
  - At least two independent and interoperable implementations are needed before any protocol extension is advanced for publication as an RFC

- Essentially in “maintenance mode”, the working group works on protocol extensions intended to make the global routing system work more smoothly and scale better
  - Many suggestions come via the GROW WG

- Other protocol work comes from BESS

- A further important piece of work is BGP-LS
  - This allows the “export” of routing information (especially TE information) from a network to a management system (such a Path Computation Element) or to another network
PIM
Protocols for IP Multicast

• There used to be several competing protocols for multicast
  – Protocol Independent Multicast - Sparse Mode (PIM-SM) “won”
    • Not widely deployed, but there are significant deployments
• Took over responsibility for IGMP and MLD
  – Used to be in INT Area
  – Puts all multicast expertise in one place
• Also a “maintenance mode” working group
  – Finalizing work to advance PIM specification to Internet Standard
  – Improving authentication and scaling of PIM
SPRING
Source Packet Routing in Networking

• A new working group with a new look at an old concept
• Each packet carries the full path that it should traverse
  – Compare with IP source route option
• Currently being worked on for MPLS and IPv6
• Ongoing work is architectural and protocol extensions where needed
• Routing protocol extensions (OSPF, IS-IS, BGP) happening in the respective working groups
Specialist Routing Protocols

• Most routing protocols are general for IP in any environment
  – This has been part of the success of the Internet

• Some environments demand very specialized routing protocols
  – The devices may be exceptionally constrained
  – The cost of sending routing updates may be very high

• These specialist problems give rise to working groups targeted at niche environments
MANET
Mobile Ad-hoc Networks

• A MANET includes routers and hosts that may be mobile and that may come and go
  – Consider battle-field environments, emergency response radio systems, or the Internet in the developing world
• MANET protocols are used in niche environments including community networks across Europe
• Work in the WG is notoriously slow and hotly debated
• Outstanding work items include...
  – DLEP : A protocol to report link characteristics to routers
  – AODVv2 : A distance vector protocol for MANETs
  – A number of extensions to OLSRv2 : A link state protocol
  – Enhanced security for MANETs
The Internet of Things (IoT) poses a new set of routing problems
  – Networks may be ad-hoc as in MANET
  – But devices may be extremely constrained in...
    • CPU
    • Power availability
    • Memory
  – Additionally, links may be subject to high degrees of interference
• The WG developed a new protocol called RPL
• Work now focused on special cases...
  – Multicast
  – Compression of routing information
  – Deployment and implementation advice for different environments
    • Factory
    • Domestic
    • Public space
    • Office
Sub-IP

• Sub-IP was, for a short time, a sub-area with its own Area Director

• Covers routing and signaling protocols for forwarding technologies that lie below IP
  – MPLS
  – Layer 2
  – Optical technologies
MPLS
Multiprotocol Label Switching

• One of the largest and most prolific working groups
• MPLS is now almost as successful as IP and Ethernet
  – Nearly all IP traffic traverses an MPLS network somewhere along its path
• The working group has progressed key technologies
  – Label Distribution Protocol (LDP)
  – Resource Reservation Protocol for Traffic Engineering (RSVP-TE)
  – Extensions to OSPF and IS-IS for Traffic Engineering
  – MPLS Transport Profile (MPLS-TP)
  – MPLS OAM
• Generic extensions to RSVP-TE, OSPF-TE, and IS-IS-TE have now moved to TEAS
• Although moving to maintenance mode, the WG still generates at least 2 RFCs every month
• Possible new work includes refinements for OAM, security, forwarding plane protection mechanisms
CCAMP
Common Control and Measurement Plane

• Responsible for Generalized Multiprotocol Label Switching (GMPLS)
  – Extensions and generalizations to RSVP-TE and OSPF-TE for non-MPLS uses
  – Largely thought of as signaling and routing for optical technologies
    • Lambda switching, TDM, OTN, flexi-grid
    • Also covers Ethernet and MPLS
• Generic extensions to RSVP-TE, OSPF-TE, and IS-IS-TE have now moved to TEAS
  – Leaves CCAMP with technology-specific work
• Potential future work includes completing flexi-grid, consideration of super-channels, routing with optical impairments
  (One current and one recent AD chaired CCAMP)
L2TP EXT
Layer 2 Tunneling Protocol Extensions

• An almost dormant working group that exists to maintain and extend the Layer 2 Tunneling Protocol (L2TP) as necessary

• Likely to be folded into PALS in the near future
TEAS
Traffic Engineering Architecture and Signaling

• A new working group formed to off-load some of the work from MPLS and to coordinate the work of MPLS and CCAMP
• Handles high level architectural views of TE
• Produces generic extensions to TE protocols
  – RSVP-TE, OSPF-TE, and IS-IS-TE
• Has oversight of protocol work from MPLS and CCAMP to see whether it should be generalized
• Mainly a maintenance-mode WG
  – Expect a constant trickle of protocol refinements and pontificating Informational I-Ds
TRILL
Transparent Interconnection of Lots of Links

• Recently moved to RTG from the INT Area
• Originally conceived as just working on a new encapsulation
• Quickly became heavily involved with the application of IS-IS to this new encapsulation
  – About half of the work needed explicit review by IS-IS experts
• Currently working on...
  – Multicast
  – An implementation report
  – Security analysis and extensions
  – Applicability to data centers
Routing Support and Operation

• In order that routing protocols can work well they need support from operational and management tools
• Operations, Management, and Administration (OAM) is a set of tools that monitor and report on the behavior of traffic flows, connections, and links
• Other management tools enable configuration and operation of the routing system through...
  – Reading information about the network
  – Injecting information into the routing system
  – Programming the routing system to behave in specific ways
**BFD**

Bidirectional Forwarding Detection

- “This will be a short-lived working group lasting only around nine months”
- BFD is a liveness monitoring OAM tool
  - Are my packets getting through?
  - Is my link / tunnel up?
- Closely coordinated with the MPLS WG
- Also some interaction with the core routing protocol working groups
- Current focus on...
  - Multicast
  - Seamless BFD for end-to-end monitoring

Jeff co-chairs BFD
I2RS
Interface To the Routing System

• Software Defined Networking (SDN) has focused on the interface from the routing or control system to the physical forwarding components
• I2RS is at a higher level looking at the interface to the routing system
• Examples include
  – Installing routes into the Routing Information Base
  – Programming route admission policies into the BGP engine
• The WG has chosen YANG as its modeling language

Jeff co-chairs I2RS
PCE
Path Computation Element

• Originally conceived as an off-board tool for computing paths in multi-domain Traffic Engineered MPLS networks
• Now finding its place as an active network management tool
• The working group mainly works on extensions to the PCE protocol (PCEP)
  – Handling sophisticated computation requirements
    • Multiple protection paths
    • Complex constraints (such as for optical networks)
  – Reporting network events
  – Supplying unsolicited updates to previously requested paths
  – Requesting new paths to be set up
• Future use cases and protocol work may arise from...
  – 6TiSCH working group in the INT Area
  – The DetNet BoF
Routing Services

• Many WGs in RTG focus on the use of existing protocols to enable new services
• Historically this has been seen in...
  – Layer 3 VPN
  – Layer 2 VPN
  – Pseudowires
• There is a recent increase in the number of new ideas in this area
• There has also been some recent consolidation of WGs
**BESS**
BGP Enabled Services

- Formed from parts of the L3VPN and L2VPN WGs
- Any service (but especially a VPN) achieved using BGP
- Close coordination with IDR for BGP extensions
- Coordination with...
  - MPLS for architectural considerations
  - NVO3 for data center VPNs
  - TRILL for EVPN interoperability
PALS
Pseudowire and LDP-enabled Services

• Formed partly from L2VPN WG and partly from PWE3 WG
• Any service enabled by LDP including...
  – Layer 2 VPNs including data center VPNs
  – Pseudowire services
• Any form of Pseudowire service
  – IP, MPLS, L2TP
  – Pseudowire encapsulations
• Likely that L2TPEXT will be folded in soon
NVO3
Network Virtualization Overlays

• A relatively new working group
• Develop a set of protocols and/or protocol extensions that enable network virtualization within a data center
  – assumes an IP-based underlay
• Progressing slowly despite aggressive milestones
• Some work now off-loaded to BESS and PALS
• A lot of time focussing on new or proprietary encapsulations
SFC
Service Function Chaining

• Arguably not a classic routing problem
• Work concerns directing flows through service function nodes to apply features such as policing, access control, security, and load balancing
• Challenges are...
  – How to associate a packet with a flow
  – How to attach “metadata” to a packet or a flow
  – How to program the next service function (node) for a flow
• Work is mainly architecture and use cases
  – Protocol work is an encapsulation header intended to be layer-agnostic
Experiments

• Sometimes in routing we act a bit cautiously
• New ideas need to be given space for experimentation, but we don’t want to qualify them as Proposed Standards until we know how they behave
  – PIM is a good example of a successful experiment that was moved onto the Standards Track
• There are currently two working groups in RTG tasked with producing Experimental RFCs
**BIER**

Bit Indexed Explicit Replication

- A new take on an old idea
  - Give every node in the network a bit in a bitmask
  - Indicate on each packet the intended recipients
  - Use routing protocols to build next-hop trees
  - Replicate packets as necessary
  - (Of course, it is a little more complicated than that)

- One challenge is whether this can be achieved without replacing all of the routers in the Internet

- This is a new and enthusiastic working group
  - Architectures and protocols are under discussion
LISP
Locator/ID Separation Protocol

- Relatively old work coming out of the Internet Research Task Force (IRTF)
- Originally conceived to handle the explosive growth of the global routing table
- Now looks at a large number of “layering” or “overlay” scenarios best typified by VPNs
- The work remains experimental while a fuller understanding of the impact is collected
- The work has an enthusiastic core of supporters
Catch-All and Specialist Work

• There is important work in the RTG Area that does not fit into any of the WGs just described

• Some of this work is advanced under the care of the AD
  – Published as AD-sponsored RFCs
  – Open discussion on the routing-discussion mailing list
RTGWG
Routing Working Group

• Some pieces of routing work don’t fit comfortably into any existing WG
  – But they may be too small to justify a new working group
• Other pieces of work are highly technical but don’t require the development of a new routing protocol
  – They describe how routers can behave to improve routing success
• The Routing (Area) Working Group is the catch-all for these
  – Do not confuse this on your agenda with the Routing Area Open Meeting
• RTGWG also acts as a venue for “mini-BoFs”
  – Proponents can float new ideas in a skilled and critical environment
    • Just a 20 or 30 minute slot

Two of the current ADs used to chair RTGWG
SIDR
Secure Inter-Domain Routing

• The Internet routing system depends on BGP
• The stability and resilience of routing tables used by BGP is under threat
  – Accidental “fat fingers”
  – Deliberate “route hijacking”
• This working group is tasked to develop a mechanism to sign route advertisements when they are originated
  – Requires a public key infrastructure
  – Requires a way to sign routes
  – Requires a way to distribute keys
A Word About YANG

- **Everyone** seems to be talking about YANG models
- There are around 120 active I-Ds with the term “YANG” in their titles or filenames [1]
  - Although some of these may belong to Chinese authors 😊
- YANG and NETCONF have replaced ASN.1 and SNMP as the configuration mechanisms of choice in the IETF
  - A more parsable modeling language
  - A more flexible protocol
- Riding on the back of a lot of OpenSource SDN work
- I2RS focuses specifically on YANG models
- Every other working group has at last one YANG model
- RTGWG acts as a home for stray routing YANG models

[1] [http://datatracker.ietf.org](http://datatracker.ietf.org)
BoFs

- There are two Birds of a Feather meetings related to routing at this IETF
  - Both aiming to form working groups
- Deterministic Networking (DetNet)
  - Looking to provide very predictable packet delivery
    - Well-know (and low) delay
    - Very small jitter
  - Particularly useful in high-density media environments
    - For example: video studios
- Simplified Use of Policy Abstractions (SUPA)
  - In the OPS Area
  - Looking to provide generic abstractions of “policy” for use in managing and operating a number of environments including routing
Closed Working Groups

• When a working group is closed it means it has finished its work
  – It *does not* the protocol it developed is dead or pointless
    • Although sometimes it does!
  – A working group should aim to close: this is good!

• Notable examples include...
  – Routing Information Protocol (RIP and RIPv2)
  – Virtual Router Redundancy Protocol (VRRP)
  – Forwarding and Control Element Separation (ForCES)

• Look at the very long list at...
Work in Other Areas

- There is work directly related to RTG done in other Areas

- **OPS Area**
  - GROW
    - Global Routing Operations
  - L3SM
    - Layer 3 VPN Service Model
  - LIME
    - Layer Independent OAM Management in Multi-Layer Environment
  - MBONED
    - MBONE Deployment

- **INT Area**
  - HOMENET
    - Home Networking
  - 6TiSCH
    - IPv6 over the TSCH mode of IEEE 802.15.4e
  - HIP
    - Host Identity Protocol
IRTF

• The Internet Research Task Force has always done work of importance to RTG
  – For years the Routing Research Group (RRG) was a key place for discussion of the next steps in routing

• Current RGs of interest are...
  – Delay-Tolerant Networking (DTNRG)
  – Global Access to the Internet for All (GAIA)
  – Network Function Virtualization (NFVRG)
  – Network Coding (NWCRG)
  – Software-Defined Networking (SDNRG)
Independent Stream

• A number of routing protocols are published as RFCs on the independent Stream

• These are not the work of the IETF
  – The only IETF review they receive is to check that they do not directly conflict with IETF work

• There is a variety of such work...
  – Proprietary protocols published so that people can implement and interoperate
  – Academic or other experiments
  – Failed ideas published for the record
  – Strange or wonderful work that the IETF was not interested to pursue

• Sometimes Independent Stream work gains traction and is brought back into the IETF for more work
Resources

• Datatracker for information about all working groups and documents
  – http://datatracker.ietf.org

• BoF wiki for details of all BoF meetings
  – http://trac.tools.ietf.org/bof/trac/

• The Routing Area wiki
  – http://trac.tools.ietf.org/area/rtg/trac

• The Routing Area Directorate’s wiki pages
  – http://trac.tools.ietf.org/area/rtg/trac/wiki/RtgDir