Autonomous Configuration

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Sir John Tenniel; Alice's Adventures in Wonderland, Lewis Carroll

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Briefing roadmap on NTP technology and performance

  - Network Time Protocol (NTP) General Overview
  - NTP Architecture, Protocol and Algorithms
  - NTP Procedure Descriptions and Flow Diagrams
  - NTP Cryptographic Authentication (Autokey)
  - NTP Clock Discipline Principles
  - NTP Precision Synchronization
  - NTP Performance Analysis
  - NTP Algorithm Analysis
  - Long-range Dependency Effects in NTP Timekeeping
NTP architecture review

- Multiple servers/peers provide redundancy and diversity.
- Clock filters select best from a window of eight time offset samples.
- Intersection and clustering algorithms pick best *truechimers* and discard *falsetickers*.
- Combining algorithm computes weighted average of time offsets.
- Loop filter and variable frequency oscillator (VFO) implement hybrid phase/frequency-lock (P/F) feedback loop to minimize jitter and wander.
The NTP subnet

- NTP synchronizes the clocks of hosts and routers in the Internet
- Time synchronization flows from primary servers synchronized via radio and satellite over hierarchical subnet to other servers and clients
- NTP provides submillisecond accuracy on LANs, low tens of milliseconds on typical WANs spanning the country
- NTP software daemon has been ported to almost every workstation and server platform available today, including Unix, Windows and VMS
- Well over 100,000 NTP clients and servers are now deployed in the Internet and its tributaries all over the world
NTP autonomous system model

- Fire-and-forget software
  - Single software distribution can be compiled and installed automatically on most host architectures and operating systems
  - Run-time configuration can be automatically determined and maintained in response to changing network topology and server availability

- Autonomous configuration (autoconfigure)
  - Survey nearby network environment to construct a list of suitable servers
  - Select best servers from among the list using a defined metric
  - Reconfigure the NTP subnet for best accuracy with overhead constraints
  - Periodically refresh the list in order to adapt to changing topology

- Autonomous authentication (autokey)
  - For each new server found, fetch its cryptographic credentials from public databases
  - Authenticate each NTP message received as sent by that server and no other
  - Regenerate keys in a timely manner to avoid compromise
Goals and non-goals

• Goals
  • Robustness to many and varied kinds of failures, including Byzantine, fail-stop, malicious attacks and implementation bugs
  • Maximum utilization of Internet multicast services and protocols
  • Depend only on public values and certificates stored in secure directory services
  • Fast operation using a combination of public-key and private-key cryptography

• Non-goals
  • Administrative restrictions (multicast group membership control)
  • Access control - this is provided by firewalls and address filtering
  • Privacy - all protocol values, including time values, are public
  • Protection against out of order or duplicated messages - this is provided by the NTP protocol
  • Non-repudiation - this can be provided by a layered protocol if necessary
Autonomous configuration and authentication - issues

- Configuration and authentication and synchronization are inseparable.
- Autonomous configuration (autoconfigure)
  - Centralized configuration management does not scale to large networks
  - Finding optimal topologies in large subnet graphs under degree and distance constraints is NP-hard
  - Greedy heuristics may not produce good topologies in acceptable time
  - Solution may involve span-limited, hierarchical multicast groups and add/drop heuristics
- Autonomous authentication (autokey)
  - Centralized key management does not scale to large networks
  - Symmetric-key cryptosystems require pairwise key agreement and persistent state in clients and servers
  - Servers cannot maintain persistent state for possibly thousands of clients
  - Public-key cryptosystems are too slow for good timekeeping
  - Solution may involve a combination of public and private key cryptosystems
**Autonomous configuration - approach**

- Dynamic peer discovery schemes
  - Primary discovery vehicle using NTP multicast and anycast modes
  - Augmented by DNS, web and service location protocols
  - Augmented by NTP subnet search using standard monitoring facilities

- Automatic optimal configuration
  - Distance metric designed to maximize accuracy and reliability
  - Constraints due to resource limitations and maximum distance
  - Complexity issues require intelligent heuristic

- Candidate optimization algorithms
  - Multicast with or without initial propagation delay calibration
  - Anycast mode with administratively and/or TTL delimited scope
  - Distributed, hierarchical, greedy add/drop heuristic

- Proof of concept based on simulation and implementation with NTP Version 4
NTP configuration scheme

- Multicast scheme (moderate accuracy)
  - Servers flood local area with periodic multicast response messages
  - Clients use client/server unicast mode on initial contact to measure propagation delay, then continue in listen-only mode

- Manycast scheme (highest accuracy)
  - Initially, clients flood local area with a multicast request message
  - Servers respond with multicast response messages
  - Clients continue with servers as if in ordinary configured unicast client/server mode

- Both schemes require effective implosion/explosion controls
  - Expanding-ring search used with TTL and administrative scope
  - Excess network traffic avoided using multicast responses and rumor diffusion
  - Excess client/server population controlled using NTP clustering algorithm and timeout garbage collection
Discovery mechanisms

- The emphasis here is on autonomous configuration and repair; discovery schemes in themselves are secondary.
- NTP multicast and/or anycast modes used to discover servers within the same hierarchical group; groups may be tiled over Internet.
- Ancestors of hierarchical group discovered from NTP peer data, augmented by NTP monitoring data.
- Authentication verified by DNS lookup and MD5 message digest.
- Database is synthesized from all these data and distributed to "interested" servers and clients.
- Interested servers and clients run a heuristic algorithm to construct hierarchical subnet topology.
Further information

- NTP home page [http://www.ntp.org](http://www.ntp.org)
  - Current NTP Version 3 and 4 software and documentation
  - FAQ and links to other sources and interesting places
- David L. Mills home page [http://www.eecis.udel.edu/~mills](http://www.eecis.udel.edu/~mills)
  - Papers, reports and memoranda in PostScript and PDF formats
  - Briefings in HTML, PostScript, PowerPoint and PDF formats
  - Collaboration resources hardware, software and documentation
  - Songs, photo galleries and after-dinner speech scripts
  - Current NTP Version software, documentation and support
  - Collaboration resources and junkbox
- Related projects [http://www.eecis.udel.edu/~mills/status.htm](http://www.eecis.udel.edu/~mills/status.htm)
  - Current research project descriptions and briefings