The Three Questions

* What is the problem?
* What is new or different?
* What are the contributions and limitations?
Historical Context

- Grapevine in everyday use: Fall 1981
- SMTP RFC: August 1982
- POP2 RFCs: October 1984, February 1985
- IMAP
  - Conceived in 1986
  - First RFC in 1988
  - First and second meetings at UW in 1996
    - Sun, Netscape announce support for IMAP4
- DNS RFCs: November 1983
Grapevine Environment

- Xerox research internet
  - Local ethernet networks
  - Gateways
  - Long distance links
- Dedicated servers
  - Alto with 128 KB RAM and 5 MB disk
  - Programmed in Mesa
    - Loosely based on Pascal
    - Support for interfaces, coroutines, exceptions, incremental compilation
Grapevine Environment
Message Service

- Provides distributed messages
  - Sent to individuals and distribution lists
- Buffered in inboxes
  - On two different servers per user for fault tolerance
  - Though, messages are not replicated, only the delivery path
- Treated as opaque objects
  - Message content not interpreted by service
- Retrieved onto client machines
- Relies on registration service…
Registration Service

- Provides naming, authentication, access control, and location function
- Based on database of *RNames*
  - Group entries contain RNames of members
  - User entries specify password, ordered list of inbox sites, connect site (for servers), and other information
- Bootstrapped on itself
  - Configuration information stored in Grapevine as well
    - GV registry (*.gv) replicated across all Grapevine servers
    - Each server represented as individual (connect site is location)
    - Each registry represented as group (members are servers)
      - gv.gv lists all servers
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...and on the messaging service

- Updates propagated through messages
Replication of registries
- Unit of replication is a registry
- No server hosts all registries
- Any server hosting a registry accepts operations

Applications rely on user-level library
- Makes multiple servers look like a single service

Overall system growth
- 1981: 5 servers, 1,500 individuals, 500 groups, 2,500 messages/day (1.7 messages/day/user)
- 1983: 17 servers, 4,400 individuals, 1,500 groups, 8,500 messages/day (1.9 messages/day/user)
A Compendium of Techniques

* Divide and conquer
  * Partition state into distinct registries
    * What limits each registry's size?
* Replicate delivery path
  * But do not replicate actual emails — why?
* Replicate registries
  * But provide only *eventual consistency* — why?
* Provide functional homogeneity
  * Every server runs the message and registry services
    * Though not all state is available on all servers
Experiences

- Effects of scale
- Configuration decisions
- Transparency
- Adjusting to load
- Operational concerns
- Reliability
Effects of Scale

- Design target: 30 servers managing 10,000 users
  - But what happens if the system grows larger?
- Global state might become limiting factor
  - Space: 15 KB for the GV registry, <1% of disk space
  - Time: Locating closest server out of 30 is acceptable
- Manual partitioning has only been partially effective
  - Distribution lists grow with population
    - E.g., Tax^\.pa has 500 members, which need to be resolved by accepting server (including locating inbox for each user)
    - Suggested solution: Distribute load through layer of indirection
      - Tax^\.all, which breaks down into per-registry lists
Effects of Scale (cont.)

- Overall message volume is a concern
  - Physical world: there's only so much paper that can be pushed around
  - Electronic world: need a better filtering mechanism
- Large number of unreliable links is a concern
  - Need store & forward architecture instead of direct delivery

- How have these concerns played out for email?
  - SMTP? Projected 2.7 trillion messages for U.S. in 2007
  - Spam? 58% of all email in May 2006
Configuration Decisions

- Organizational structure for email inboxes
  - Encourages sharing of data
    - Same email stored only once
      - In 4.7 inboxes on average, maximally 300
  - Has natural scalability limits
    - There's only so many people that can collaborate effectively

- Geographical structure for registries
  - Relatively stable within commercial organization
    - Unlike the organizational hierarchy...
  - But can be an arbitrary criterion in the real world
    - One group split evenly between El Segundo and Palo Alto
More Configuration Decisions

- Location of registry replicas
  - Close to inboxes for that registry
  - Close to servers accepting messages to distribution lists
  - On both sides of unreliable links
  - On enough machines to avoid catastrophic losses
    - Constraints 2-4 lead to three replicas
  - Not on busy servers

- Ph, that's an awful lot to consider for an administrator
Transparency

- Works well in common case but leads to surprising results in some uncommon cases
  - Propagation delay in registry updates
    - Client library may pick different server for next operation
  - Expensive consequences of simple operations
    - Changing inbox list originally caused remailing of entire inbox
  - No notion of distance of server
    - Long delays when using nonlocal server
  - Little information on overall state of the system
    - Unused distribution lists, inaccessible servers, duplicate msg's
Adjusting to Load

- Naïve algorithm kills your performance
  - Sending whole object updates instead of deltas/operations
    - Adding/removing one member to/from list is frequent
  - Not distinguishing between users and groups
    - Need to look up every single name for access control
    - What about flattened groups?
  - Assuming that all mailbox access is sequential
    - Users move about and leave their mail on the server
Operational Concerns

- GV experts are few; operators need not be qualified
  - Operators reboot servers, load programs, fix hardware
- SSH is your friend
  - Well, at the time: remote disk editor, viticulturist's entrance
    - "a cultivator of grape vine"
- Logs are your friend
  - Provide more than a week of history
  - But need to be combined from different servers
    - Unique identifiers help
  - Can be viewed dynamically
    - Check fixes, notice oddities
- The "dead letter facility" is a good idea?
Reliability

- System requires spare capacity to work
  - Detecting resource depletion early is crucial
  - But system still needs to work without resources
- Servers being treated as equals can be a burden
  - Circuit manufacturing facility builds on Grapevine
  - But can become backup when rest of system overloaded
- Message server depends on email archive
  - Helps reduce storage space, but?
  - Also, archiving is triggered by what?
"This reluctance is partly due to the potential disruption that introduced bugs would have on the large user community that depends on Grapevine services to get its work done."

What happened here?
What Do You Think?