Crowds: Anonymity for web browsing

- **Why not just use mix-nets or dc-nets?**
  - Need low-latency responses
  - Too much computational overhead
  - Can get away with weaker adversarial model
- **Idea: Introduce new crowds paradigm**

Anonymity goals

- **Sender anonymity**
  - Don't know who sent a message
  - Might see servers receiving messages
- **Receiver anonymity**
  - Don't know who is receiving messages
- **Unlinkability of sender and receiver**
  - Might know which clients are talking and which servers
  - Don't know which client is talking to which server

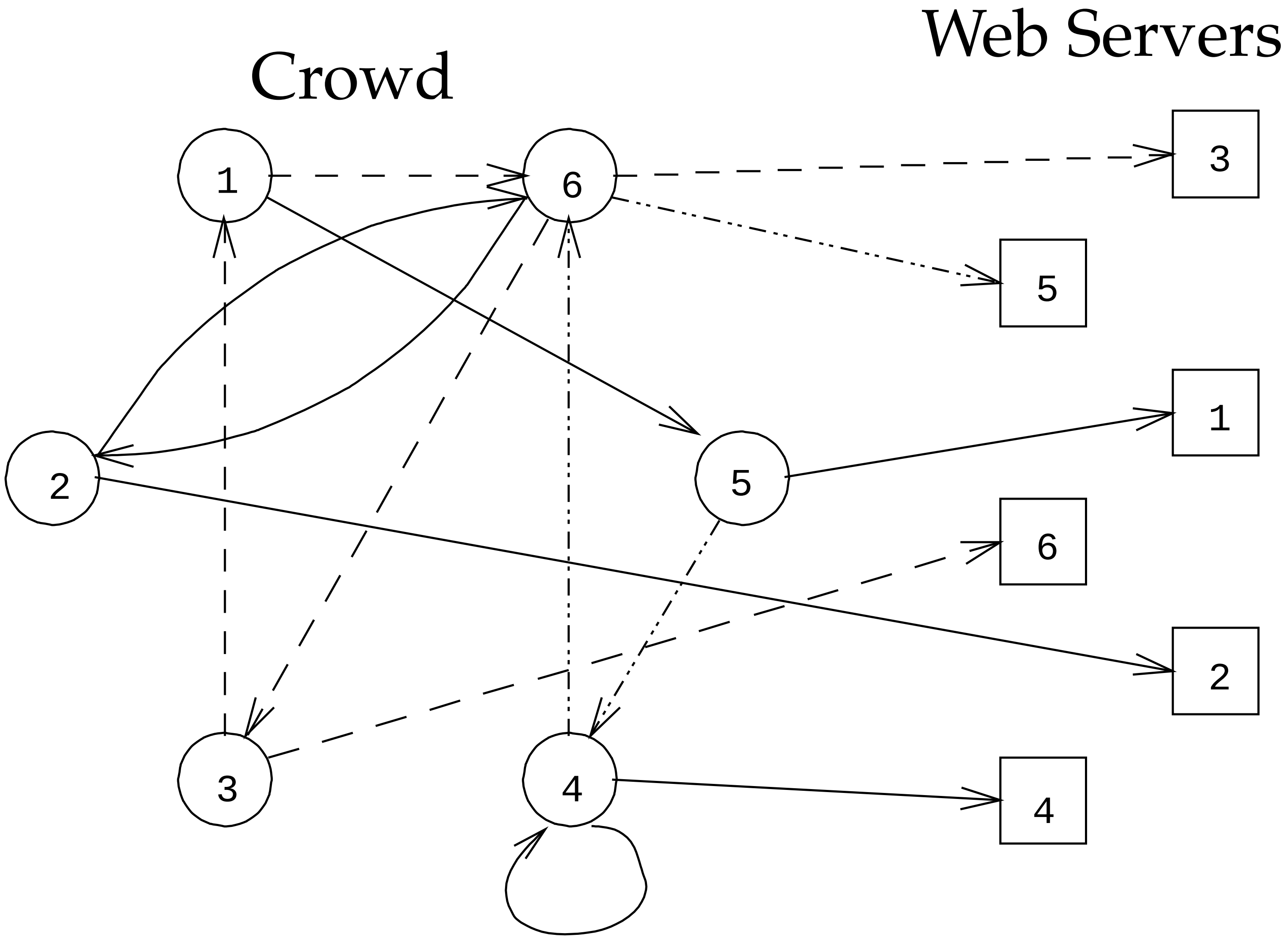
Levels of security

- **Absolute privacy**
- **Beyond suspicion**
  - Sender/originator completely uncorrelated
- **Probable innocence**
  - Originator is not sender with at least 50% probability
- **Possible innocence**
  - Sender has non-trivial probability of not being originator
- **Exposed / Provably exposed**

Adversarial model

- **Local eavesdropper**
  - Observes all traffic to/from a user's machine
- **Collaborating crowd members**
  - Can deviate from protocol and share info to expose users
- **The end server**
  - A web server trying to figure out identity of users

Crowds architecture



Implementation

- **Each client machine runs a *jondo* process**
  - Acts as a web proxy
  - All jondos know about each other
- **Jondos forward requests to each other**
  - First request from browser gets forwarded to random jondo
  - At subsequent hops, gets forwarded with prob p_f

Paths

- **System uses static paths between clients and servers**
  - Chosen on first access to server by client
  - Same for all subsequent requests
  - Changes only when new jondos join, or jondo dies
  - Why static paths?
- **What happens if bad jondo dies to force new path creation?**
- **Last jondo parses HTML, prefetches images…why?**

Anonymity properties

Attacker	**Sender anonymity**	**Receiver anonymity**
local eavesdrp	exposed	$(n \to \infty)$ beyond susp
c bad jondos	prob innocence $(n \to \infty)$ abs priv	$(n \to \infty)$ abs priv
server	beyond susp	N/A

Stretch break

Nym.alias.net pseudonym service

- **People establish email pseudonyms or *nyms***
  - e.g., incognito@nym.alias.net
- **Nyms function like regular email addresses**
  - People can send and receive mail under a nym
- **Nym owners are anonymous**
  - Identities unknown even to the nym.alias.net administrators

In real use outside of CS research

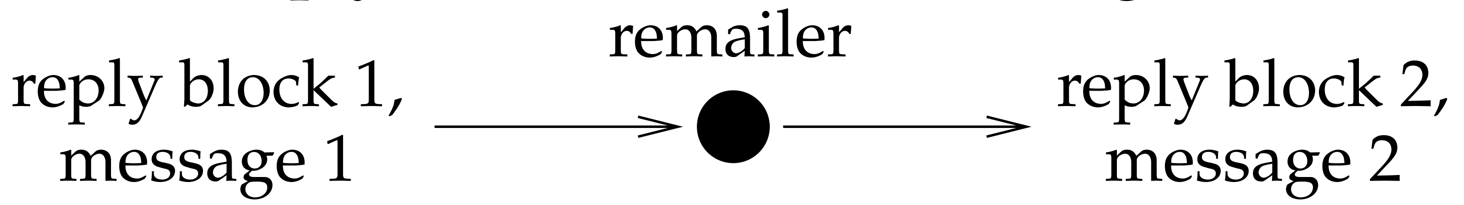
- **In public use since June, ’96**
- **Requires only PGP to use**
- **Software clients for DOS/Windows/Unix**
- **Consistently has 2,000–3,000 active nyms**
- **Provides auxilliary services:**
  - Anonymous remailer, mail-to-news gateway

Nym.alias.net design

- **Built on existing anonymous remailer network**
  - Independently operated remailers span several countries
  - Remailers used as a watered-down *mix-net* [Chaum '81]
  - Multiple nodes must be compromised to expose a nym user
- **Deployment favored over privacy**
  - Use of PGP, existing remailers hurt security
  - Much subsequent work since '81 could not be used
  - Our experience nonetheless relevant to future systems
    - No known technical attacks have occured on privacy
    - Privacy still unbreakable by us, the administrators

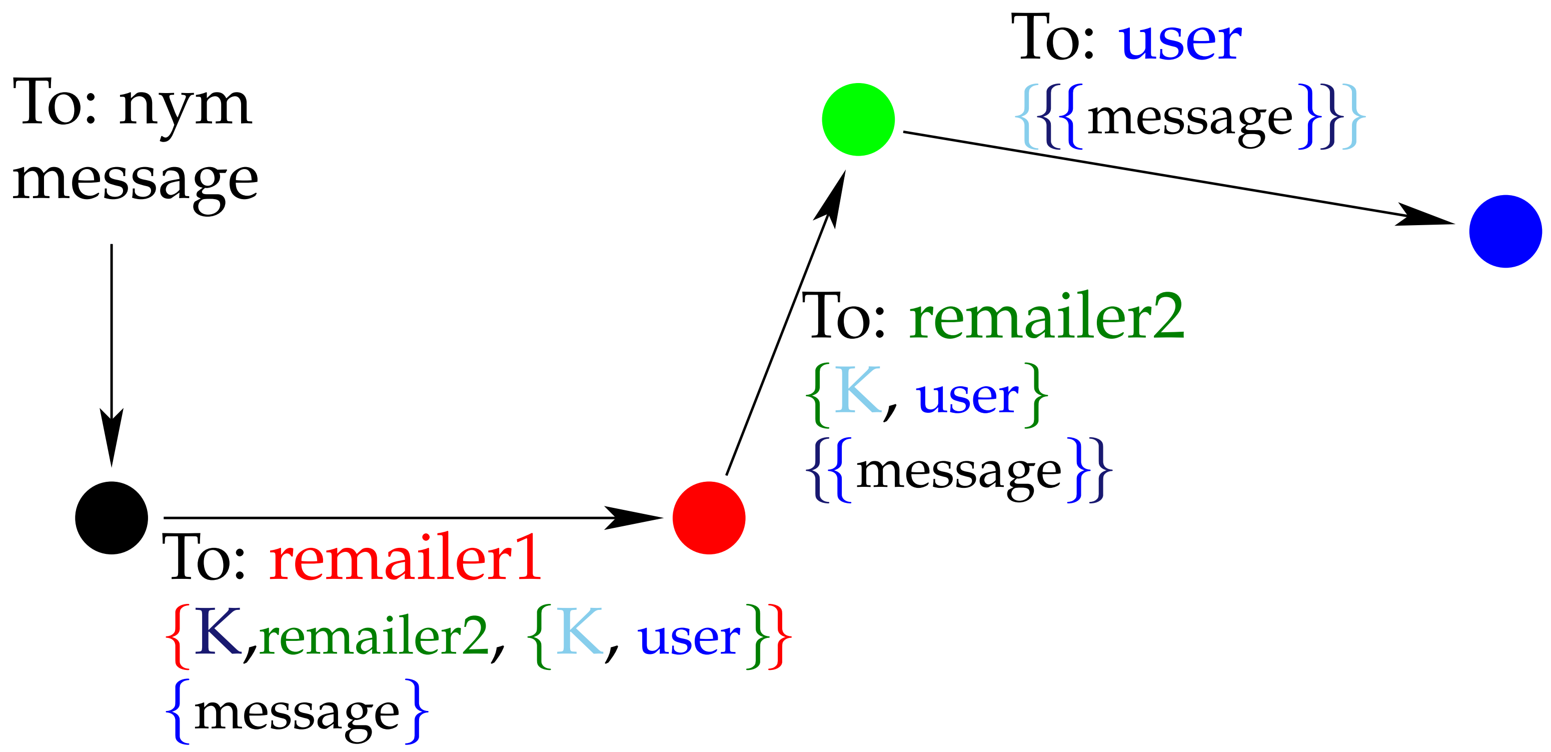
Implementation details

- **Independent remailers each have a public key**
- **Every nym has a *reply block***
- **Reply blocks route mail through remailers**



- **Example reply block:** $\{\mathbf{K}, \mathbf{user}\}_{K_2}$
  - Encrypted with K_2, only remailer2 can decrypt
  - Remailer2 encrypts message with K, forwards it to user
  - Without K_2^{-1}, reply block hides identity of user

Path of mail received by pseudonyms



- **How much privacy against various attackers?**

People use nym.alis.net…

- **Under oppressive governments**
- **When risking embarrassment, harassment, job loss**
  - discussing alcoholism, depression, being a sexual minority
  - whistle-blowing, fighting harmful cults
- **To keep correspondents out of mail log files**
- **To prevent every public statement from staying with them for life**

○ **For admittedly marginal purposes**

  ○ marijuana cultivation, virus development, piracy

Anonymous services draw attacks

- **Anonymous speech can upset people**
  - Used to express unpopular opinions
  - Used to criticize people who respond vindictively
  - Used to denounce powerful organizations/governments
  - Abused to harass people, escaping responsibility
- **Anger redirected against anonymity provider**

Two threats to anonymous services

- **Attempts to expose users' identities**
  - Eavesdropping, flooding, traffic analysis
  - Corrupt/compromised servers
- **Attempts to silence users or shut down service**
  - Attack anonymous server
  - Attack someone else with anonymous server
  - Marginalize service so everyone ignores it
  - Make life intolerable for someone who can close server

Defense poses unusual challanges

- **Privacy concerns preclude usage logs**
- **Service designed to hide identities (abusers too)**
- **Attackers cannot be banned even when known**
- **Filtering or content-based censorship impractical**
  - Human adversaries adapt to filtering
  - Content filters may block legitimate use (goal of attack)
  - Too much human effort to review all messages
  - Filtering exposes service providers to liability

Types of attack

- **Conventional attacks (as with non-anon. servers)**
  - Lack of logs may complicate defense
  - Find alternate places to record information
  - Short-term records may be permissible where logs not
- **Content-based attacks**
  - Help recipients ignore unwanted anonymous traffic
  - Keep what's ignored secret from attacker
- **Overloading attacks**
  - Ignoring not sufficient when many resources at stake
  - Overloading can cost attacker his anonymity
  - Push cost back onto attacker

Harassment

- **Unwanted offensive/threatening anonymous mail**
- **Solution: destination blocking**
  - Drop messages to those who don’t want anonymous mail
- **Automatic destination blocking process**
  - User sends mail to *dstblk-request@nym.alias.net*
  - System requests confirmation (nonce in return address)
  - Mailing list blocking requires consent of list owner (check that *owner-address*, etc. bounce, first)
- **Keep destination block list secret from senders**

Mail-bomb

- **One person can overload the system with mail**
- **Solution: custom mail server throttles attack**
  - Short-term history sufficient to detect attack
  - Temporary SMTP error codes, SYN filtering delay mail
  - Exploited mail relays fill up, can use logs to deal with it
  - Direct clients use many PCBs, but no connections

Reverse mail-bomb

- ***help@nym.alias.net*** **replies to mail with help file**
- **Attacker flooded *help* with forged mail**
- **Hard to track down perpetrator without mail logs**
- **Any logs might seriously hurt privacy**
  - Many help requests presumably not anonymous
  - Likely correlation between help requests & new nyms
- **Solution: return sender information with help file**

Spam-baiting 1

- **Software allowed poor news forgeries**
- **Posts to some newsgroups precipitate spam mail**
  - *misc.entrepreneurs*, *biz.mlm*, *alt.sex.erotica.marketplace*, …
- **Attacker forged articles to these newsgroups**
  - Forgery victims flooded with spam
- **Anon. mail incited victims to attack remailers**
- **Solution: prevent forgeries**

Spam-baiting 2

- **Attacker posted lists of email addresses**
- **Victims demanded we filter against their addresses**
  - Would conveniently block anonymous followups
- **Censorship failed**
- **Solution: post more bad addresses than good ones**

Problem: creating many accounts

- **Someone started creating many accounts**
  - In the extreme, could run the server out of files
  - Could circumvent per-account traffic limits for bulk email
- **First solution: require account confirmation**
- **If problem recurs**. . .
  - PGP key generation requires both CPU and human time
  - All accounts created had same PGP key (prohibit this)
- **If attacker hacks PGP key generator**. . .
  - Increase CPU cost (e.g. hashcash [Back])
  - Increase human cost (e.g. GIF to ASCII challenge)

Defending anonymous systems

- **Conventional attacks (as with non-anon. servers)**
  - Lack of logs may complicate defense—keep info elsewhere
  - Short-term records may be permissible where logs not
- **Overloading attacks**
  - Make overloading cost the attacker his anonymity
  - Push cost back onto attacker
  - Put the human in the loop
- **Content-based attacks**
  - Let people easily ignore anonymously published content
  - Never store and serve objectionable content

Lessons learned

- **Factor abuse into design of anonymous services**
  - People will get angry at existence of service
  - People will exploit the system to attack itself
- **The most precious resource is often human time**
  - Attackers can win by forcing human service operator to "clean up the mess"
- **Avoid storing and serving objectionable content**
  - But *don't* have humans categorizing published data

Putting the lessons to use

- **Tangler: A censorship-resistant publishing system [Waldman & Mazières]**
- **Goals of a censorship-resistant publishing system**
  - Let anyone pseudonymously publish, update documents
  - Make it impractical to suppress published information
  - Harden the system against attackers who abuse it

Tangler overview

- **Architecture: World-wide server network**
  - Assume ~ 20 Tangler servers around the world
  - Run by volunteers, as with anonymous remailers
  - System highly tolerant of server failures
- **Published documents broken into blocks**
  - Agree upon mapping from each block to several servers
  - Publisher stores blocks on appropriate servers
  - Clients fetch blocks to reconstruct documents

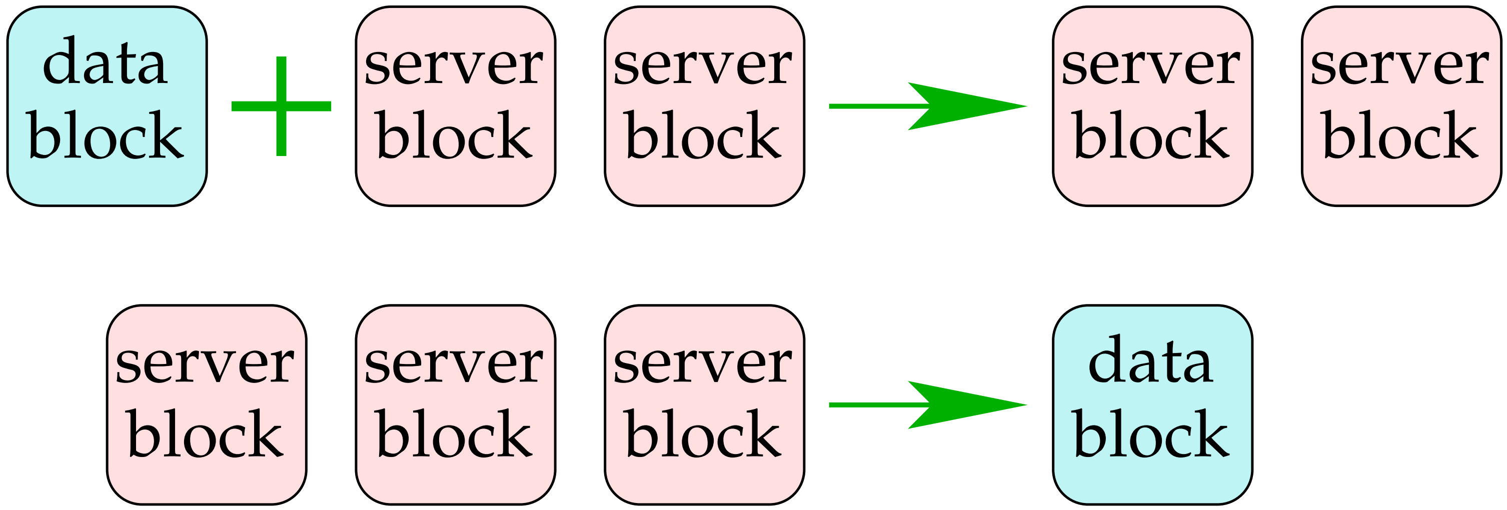
Challenges

- **Providing anonymity to publishers**
- **Flooding attacks – consume all storage on system**
- **Malicious servers**
  - Drop blocks from a particular document
  - Replace blocks with "redacted" versions
- **Publisher must be able to update documents**
- **Objectionable/illegal content**
  - Anthrax recipes, libel, decss, "abortionist" home addresses, . . .
  - Didn't I just say not to store and serve this stuff?
  - But if some mechanism allowed us to suppress it, cults would compel us also to suppress documents that expose them

Dealing with objectionable content

- **Dissociate blocks served from documents published**
  - No server should serve blocks of objectionable documents
- **Dissociate servers from blocks served**
  - Blocks should migrate regularly between servers
  - By the time someone takes action against a server, its blocks should have moved somewhere else
- **Dissociate block→server assignment from server**
  - A server cannot chose which blocks to store and serve
  - Misbehaving servers should be automatically ejected

Document entenglement



- **Published data blocks broken into 4 server blocks**
  - 2/4 server blocks from previously published documents
  - Any server block information-theoretically unrelated to data
  - Any server block may be part of multiple data blocks
  - No single server block necessary to reconstruct data

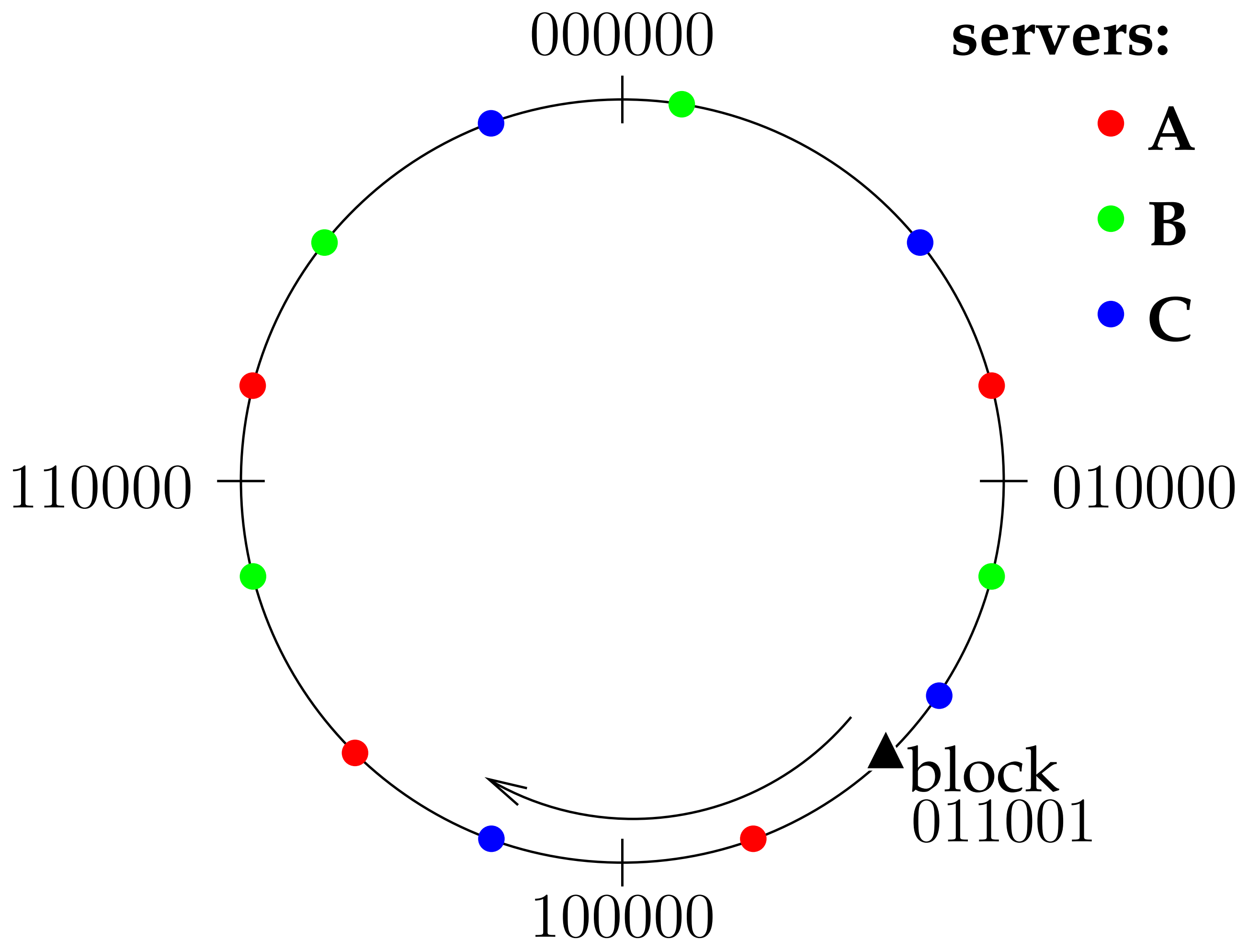
Document collections

- **Server blocks named by SHA-1 hash**
- **Data blocks named by 4 server block hashes**
  - Can reconstruct data from any 3 matching server blocks
- **Collection data structure maps file names to data blocks**
  - Metadata much like in SFSRO
  - Collection broken into blocks, themselves entangled
  - Root block of collection digitally signed w. version number
  - Only owner of collection key can update contents

Block-to-server mapping

- **Every server is assigned a number of IDs**
  - Each server has known pub. key, K, and capacity N GB
  - If d is number of days since Jan 1, 1970, server's IDs are: $H\left(K, \lfloor dN/14 \rfloor - N\right), \ldots, H\left(K, \lfloor dN/14 \rfloor - 1\right), H\left(K, \lfloor dN/14 \rfloor\right)$
  - $1/14$ of IDs change every day, all points change in 2 weeks
- **Map server IDs and block hashes onto circle**
  - Store blocks at successor servers around circle [KLLLLP97]
  - Minimizes incorrect placement when servers join/leave

Block lookup



Ingress control

- **Each server can consume space proportional to its capacity**
  - If server A has capacity C_A, B has C_B, and total capacity is C, then A can store $C_A C_B / C$ blocks on B.
  - Servers themselves can use a variety of ingress-control techniques (as with remailers)
- **Space is committed through blind *storage credits***
  - A constructs message $m =$ “I agree to store block $H(x)$”
  - B digitally signs m *blindly* (cannot see message signed)
  - A later anonymously ships $\langle m, \text{sig}, x \rangle$ to B
  - B digitally signs *receipt*: “I have received $H(x)$”
  - At end of day, B signs *commitment* of all blocks accepted

Malicious servers

- **Goal: Easily prove misbehavior to eject servers**
- **Some attacks cause server to contradict itself**
  - Server signs receipt for x, but x not in committment
  - Server requests too many credits
- **Otherwise can relay any request through a witness**
  - Server signed commitment but cannot produce block
  - Server signed credit but won’t issue receipt
- **Entanglement maximizes chances of catching bad servers**
  - Retrieves random blocks from committment—audit
  - Causes people to care about each other’s server blocks