Decentralised Communication: The challenge of balancing interoperability and privacy.

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http://www.matrix.org

The problem:

Users are locked into proprietary communication apps.

They have no control over their data or their privacy.

Worse still, each app is a closed silo – forcing users to install redundant apps and fragmenting their comms.

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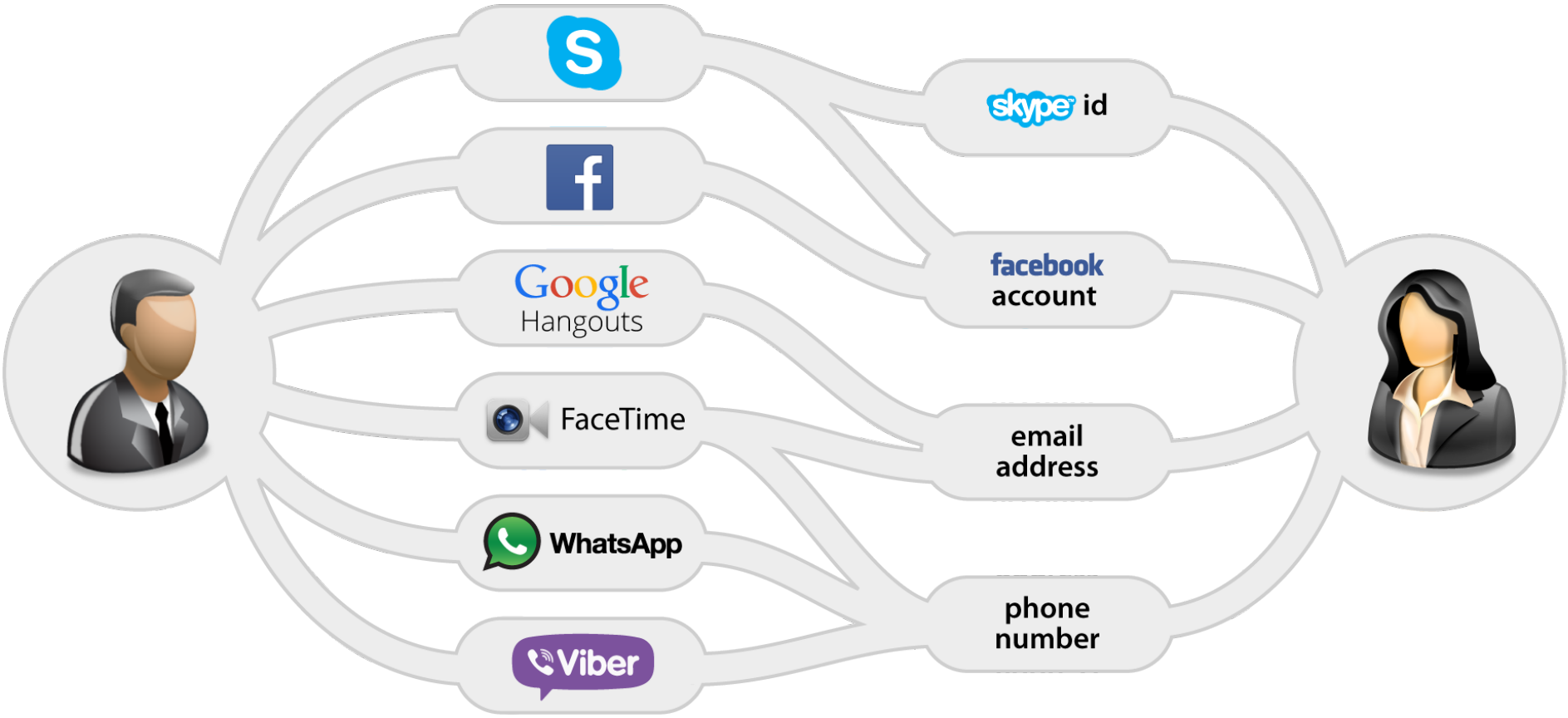
Google
Hangouts
FaceTime
WhatsApp
Viber
skype id
facebook
account
email
address
phone
number

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I want to communicate with the apps and services I trust.

Not be forced into specific services chosen by my contacts.

If email gives me that flexibility, why not VoIP and IM?

Enter Matrix

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Open
Decentralised
Persistent
Eventually Consistent
Cryptographically Secure
Messaging Database
with JSON-over-HTTP API.

Matrix is for:

- Group Chat (and 1:1)
- WebRTC Signalling
- Bridging Comms Silos
- Internet of Things Data

…and anything else which needs to pubsub persistent data to the world.

Matrix was built to liberate your scrollback.

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1st law of Matrix: Conversation history and Group comms are the 1st class citizens.

2nd law of Matrix:
No single party own your conversations – they are shared over all participants.

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3rd law of Matrix:
All conversations may be end-to-end encrypted.

(real soon now)

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Matrix is:

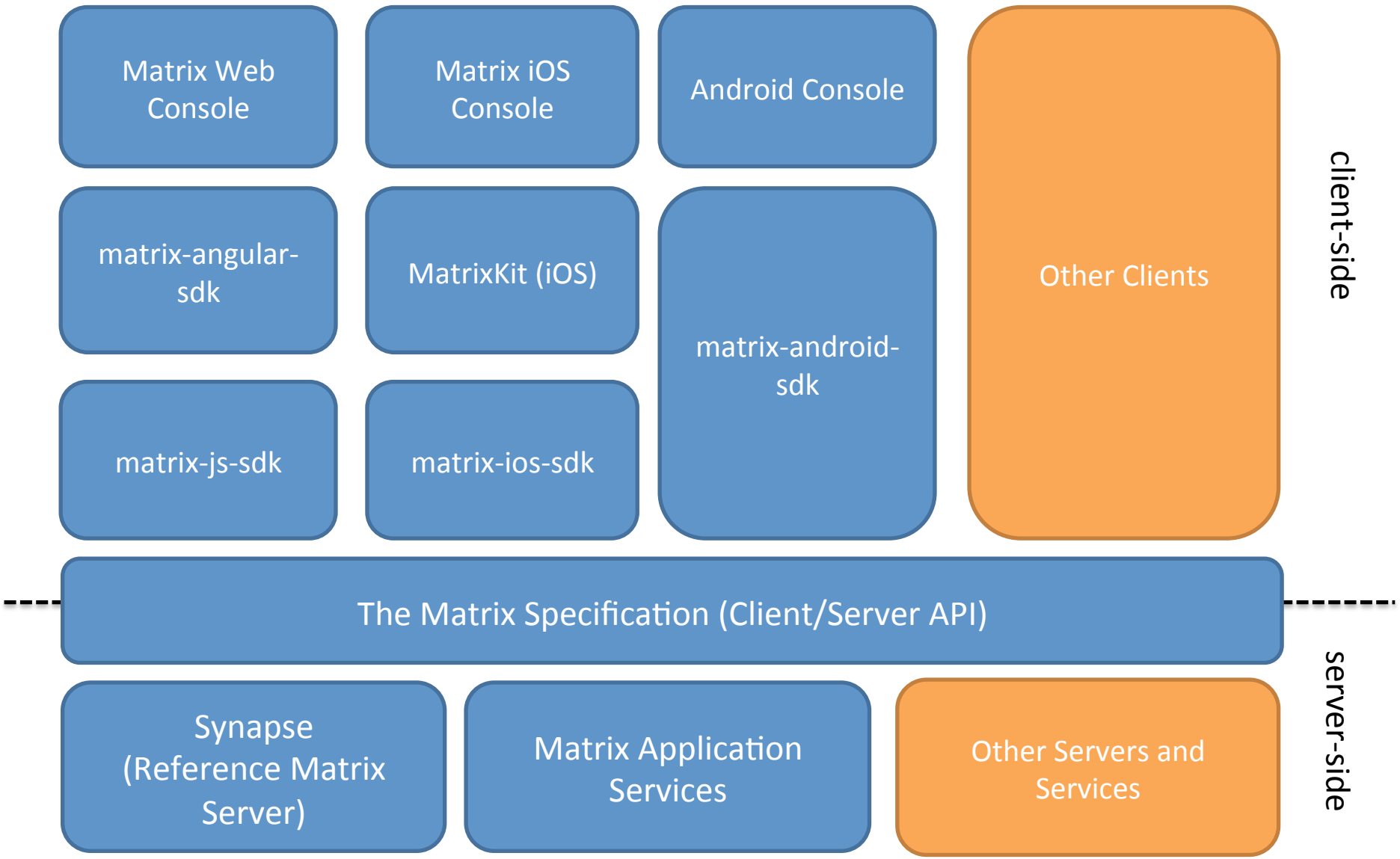
- Non-profit **Open Source Project**
- De-facto **Open Standard HTTP APIs**:
  - Client <-> Server
  - Server <-> Server
  - Application Services <-> Server
- Apache-Licensed Open Source **Reference Impls**
  - **Server** (Python/Twisted)
  - **Client SDKs** (iOS, Android, JS, Angular, Python, Perl)
  - **Clients** (Web, iOS, Android)
  - **Application Services** (IRC, SIP, XMPP, Lync bridges)
- A **whole ecosystem** of 3rd party servers, clients & services

What does it look like?

Demo time!

http://matrix.org/beta

The Matrix Ecosystem



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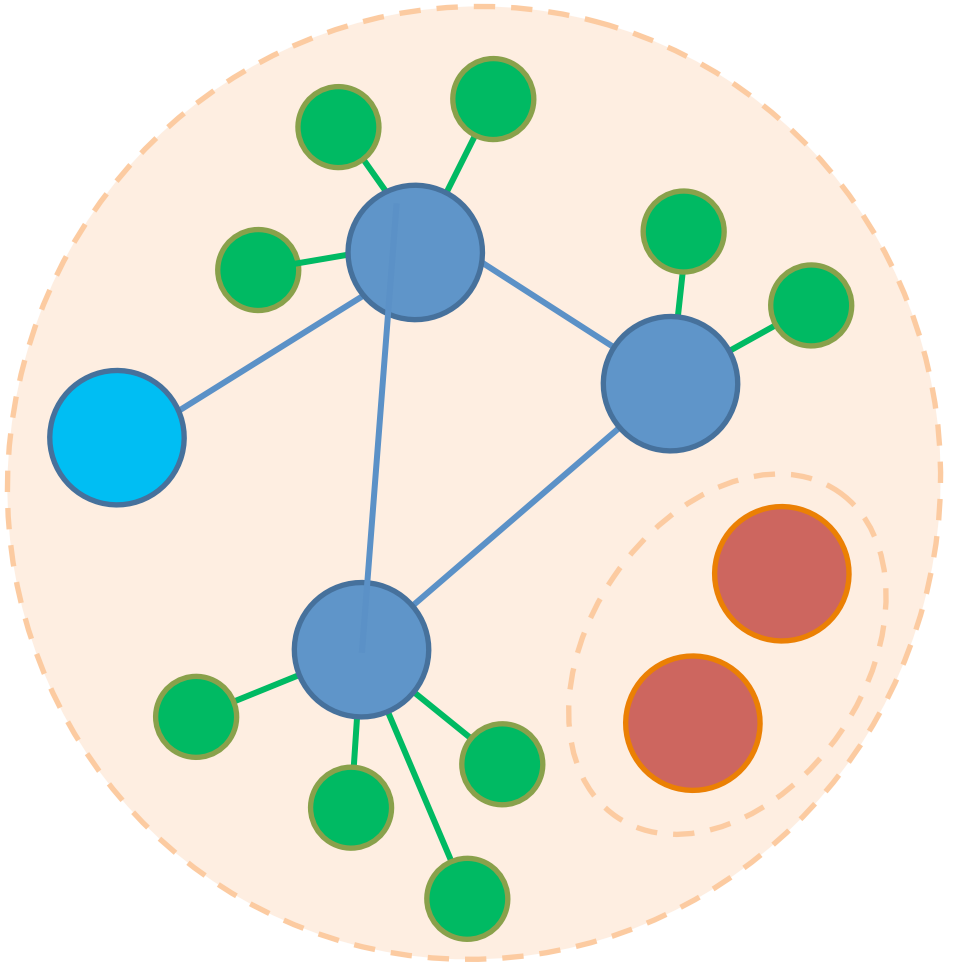
Matrix Architecture

Clients

Home Servers

Application Servers

Identity Servers



Functional Responsibility

- **Clients**: Talks simple HTTP APIs to homeservers to push and pull messages and metadata. May be as thin or thick a client as desired.
- **Homeservers**: Stores all the data for a user - the history of the rooms in which they participate; their public profile data.
- **Identity Servers**: Trusted clique of servers (think DNS root servers): maps 3rd party IDs to **matrix** IDs.
- **Application Services:** Optional; delivers application layer logic on top of Matrix (Gateways, Conferencing, Archiving, Search etc). Can actively intercept messages if required.

How does it work?

http://matrix.org/#about

The client-server API

To send a message:

```
curl -XPOST -d '{"msgtype":"m.text", "body":"hello"}'
"https://alice.com:8448/_matrix/client/api/v1/rooms/
ROOM_ID/send/m.room.message?access_token=ACCESS_TOKEN"
```

```
{
    "event_id": "YUwRidLecu"
}
```

The client-server API

To set up a WebRTC call:

```
curl -XPOST -d '{\
  "version": 0, \
  "call_id": "12345”, \
  "offer": {
    "type" : "offer”,
    "sdp" : "v=0\r\no=- 658458 2 IN IP4 127.0.0.1…"
  }
}' "https://alice.com:8448/_matrix/client/api/v1/rooms/
ROOM_ID/send/m.call.invite?access_token=ACCESS_TOKEN"

{ "event_id": "ZruiCZBu” }
```

Basic 1:1 VoIP Matrix Signalling

```
    Caller                          Callee
m.call.invite ----------->
m.call.candidate -------->
[more candidates events]
                              User answers call
                    <------ m.call.answer
                [media flows]
                    <------ m.call.hangup
```

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The client-server API

To persist some MIDI:

```
curl -XPOST -d '{\
    "note": "71",\
    "velocity": 68,\
    "state": "on",\
    "channel": 1,\
    "midi_ts": 374023441\
}' "https://alice.com:8448/_matrix/client/api/v1/rooms/
ROOM_ID/send/org.matrix.midi?access_token=ACCESS_TOKEN"

{ "event_id": “ORzcZn2” }
```

The server-server API

```
curl -XPOST -H 'Authorization: X-Matrix origin=matrix.org,key="898be4…",sig="j7JXfIcPFDWl1pdJz…"' -d '{
    "ts": 1413414391521,
    "origin": "matrix.org",
    "destination": "alice.com",
    "prev_ids": ["e1da392e61898be4d2009b9fecce5325"],
    "pdus": [{
        "age": 314,
        "content": {
            "body": "hello world",
            "msgtype": "m.text"
        },
        "context": "!fkILCTRBTHhftNYgkP:matrix.org",
        "depth": 26,
        "hashes": {
            "sha256": "MqVORjmjauxBDBzSyN2+Yu+KJxw0oxrrJyuPW8NpELs"
        },
        "is_state": false,
        "origin": "matrix.org",
        "pdu_id": "rKQFuZQawa",
        "pdu_type": "m.room.message",
        "prev_pdus": [
            ["PaBNREEuZj", "matrix.org"]
        ],
        "signatures": {
            "matrix.org": {
                "ed25519:auto": "jZXTwAH/7EZbjHFhIFg8Xj6HGoSI+j7JXfIcPFDWl1pdJz+JJPMHTDIZRha75oJ7lg7UM+CnhNAayHWZsUY3Ag"
            }
        },
        "origin_server_ts": 1413414391521,
        "user_id": "@matthew:matrix.org"
    }]
}' https://alice.com:8448/_matrix/federation/v1/send/916d630ea616342b42e98a3be0b74113
```

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Application Services (AS)

- Extensible custom application logic
- They have privileged access to the server (granted by the admin).
- They can subscribe to wide ranges of server traffic (e.g. events which match a range of rooms, or a range of users)
- They can masquerade as 'virtual users'.
- They can lazy-create 'virtual rooms'
- They can receive traffic by push.

Uses for AS API

- Gateways to other comms platforms
  e.g.: all of Freenode is available at #freenode_#foo:matrix.org
- Data manipulation
  - Filtering
  - Translation
  - Indexing
  - Mining
  - Visualisation
  - Orchestration
- Application Logic (e.g. bots, IVR services)
- …

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A trivial application service

```
import json, requests  # we will use this later
from flask import Flask, jsonify, request
app = Flask(__name__)

@app.route("/transactions/<transaction>", methods=["PUT"])
def on_receive_events(transaction):
    events = request.get_json()["events"]
    for event in events:
        print "User: %s Room: %s" % (event["user_id"], event["room_id"])
        print "Event Type: %s" % event["type"]
        print "Content: %s" % event["content"]
    return jsonify({})

if __name__ == "__main__":
    app.run()
```

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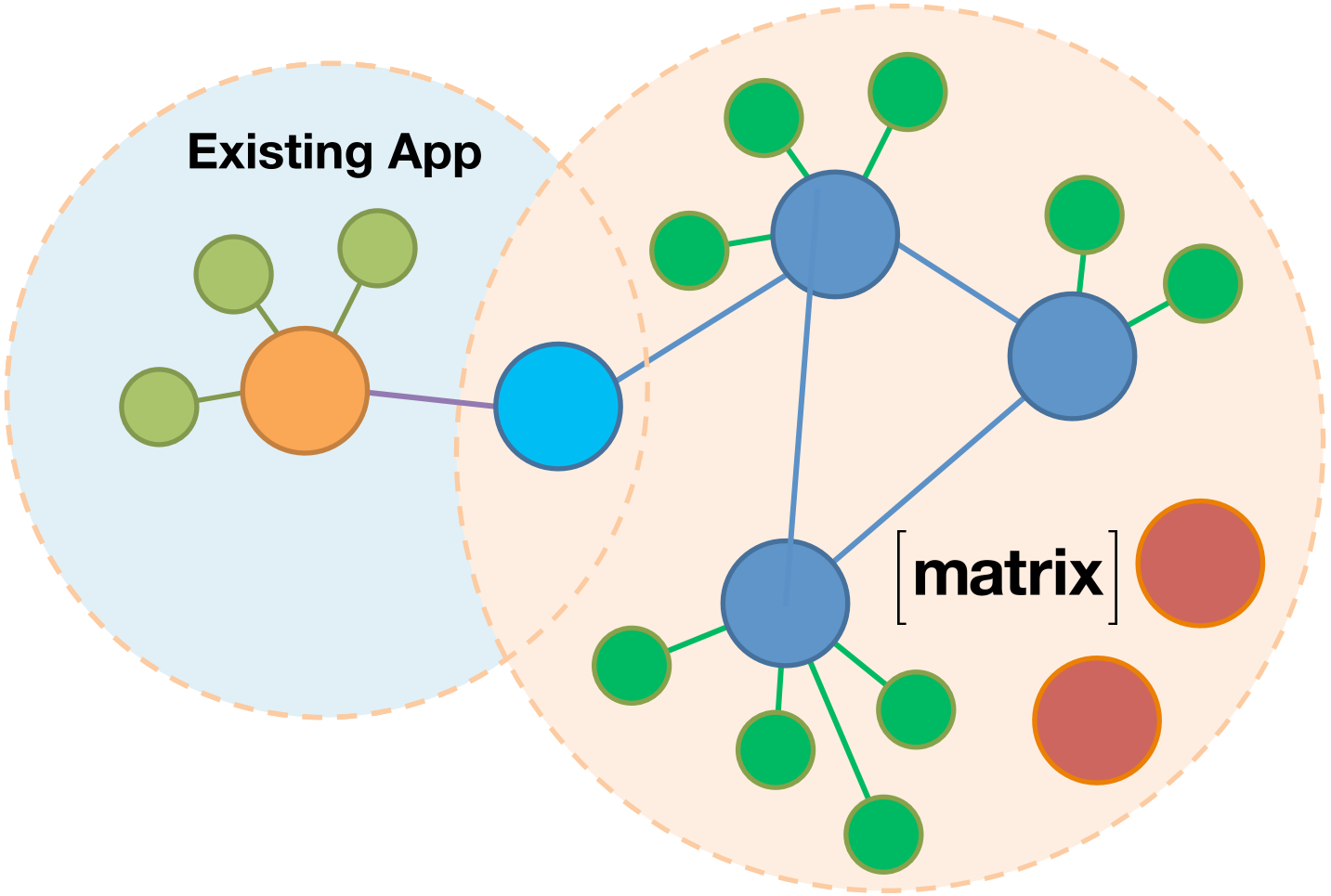
Matrix Bridging with ASes



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Current Progress

- Funded May 2014
- Launched alpha Sept 2014
- Entered beta Dec 2014
- Stable v0.9 Beta May 2015
- July 2015: v1.0 release?!

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What's next?

- Rolling out E2E encryption
- Reusable web UI components and improving the web client
- Multi-way VoIP
- Lots more Application Services
- Landing V2 APIs
- Use 3rd party IDs by default
- Yet more performance work
- Spec polishing
- New server implementations!

We need help!!

- We need people to try running their own servers and join the federation.
- We need people to run gateways to their existing services
- We need feedback on the APIs.
- Consider native Matrix support for new apps
- Follow @matrixdotorg and spread the word!

Privacy in Matrix

Two basic types of privacy:

1. Can attackers see what you're saying?

2. Can attackers see who you're talking to, and when?

Matrix can protect the contents of what you're saying using end-to-end encryption.

Neither the servers nor the network can decrypt the data; only invited clients.

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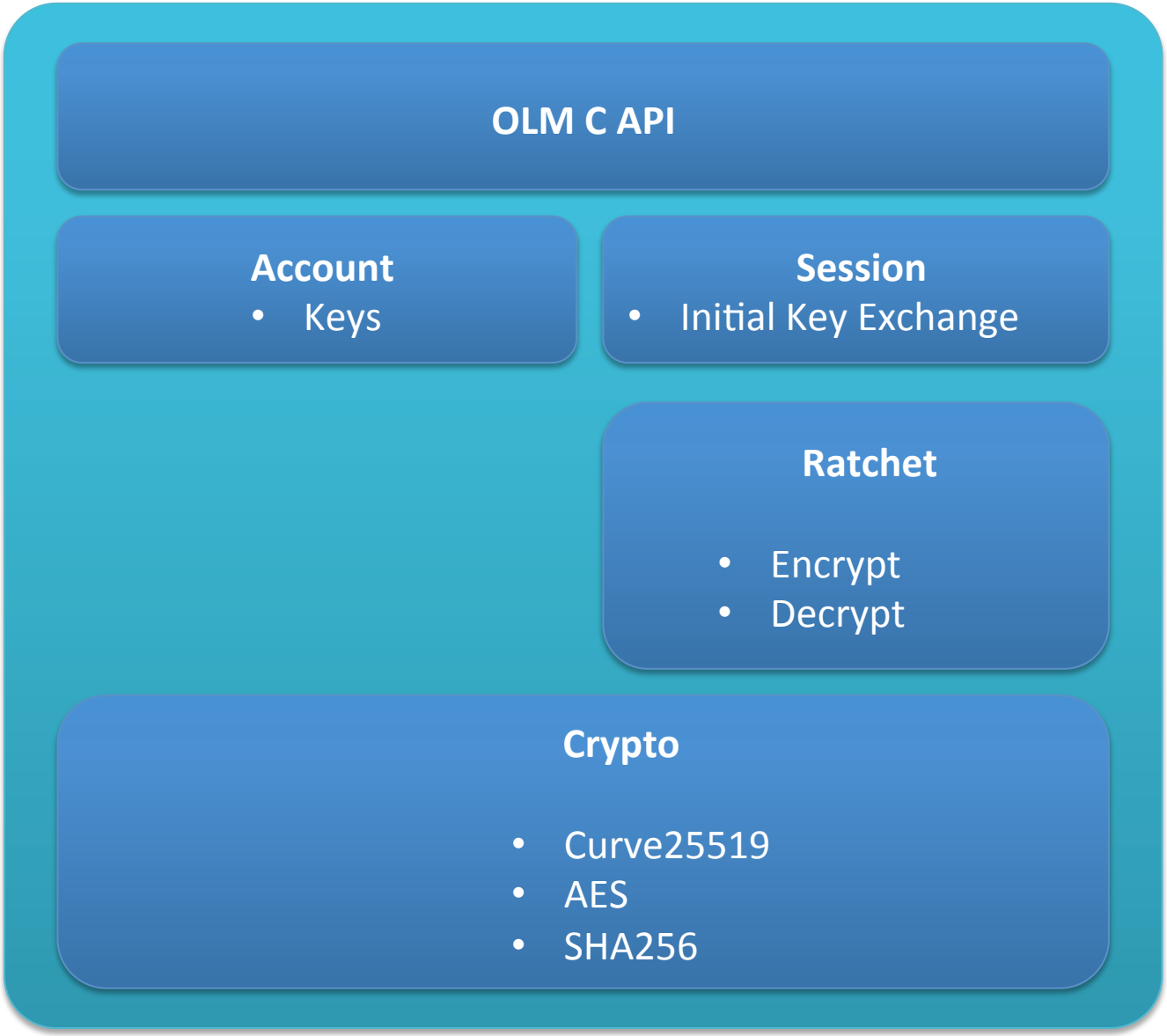
Introducing Olm
(new as of today!!!)

https://github.com/matrix-org/olm

Olm

- Apache License C++11 implementation of Axolotl, exposing a C API.
- Axolotl is Open Whisper System's better-than-OTR cryptographic ratchet, as used by TextSecure, Pond, WhatsApp etc.
- Supports encrypted asynchronous group communication.
- 130KB x86-64 .so, or 208KB of asm.js


OLM C API
Account
• Keys
Session
• Initial Key Exchange
Ratchet
• Encrypt
• Decrypt
Crypto
• Curve25519
• AES
• SHA256

Alice

Bob

Alice and Bob both generate identity (I) & ephemeral (E) elliptic curve key pairs

Initial Shared Secret (ISS) =
ECDH(Ea, Ib) +
ECDH(Ia, Eb) +
ECDH(Ea, Eb)

Discard Ea
Derive chain key from ISS (HMAC)
Derive message key (K_0) from chain key (HMAC)
Derive new chain key ← **hash ratchet**
M_0 = Message plaintext
C_0 = Authenticated Encryption of (M_0, K_0)
Ra_0 = generate random ratchet key pair
Ja_0 = incremental counter for each hash ratchet advancement

Ia, Ea, Eb, Ra_0, Ja_0, C_0

Alice

Bob

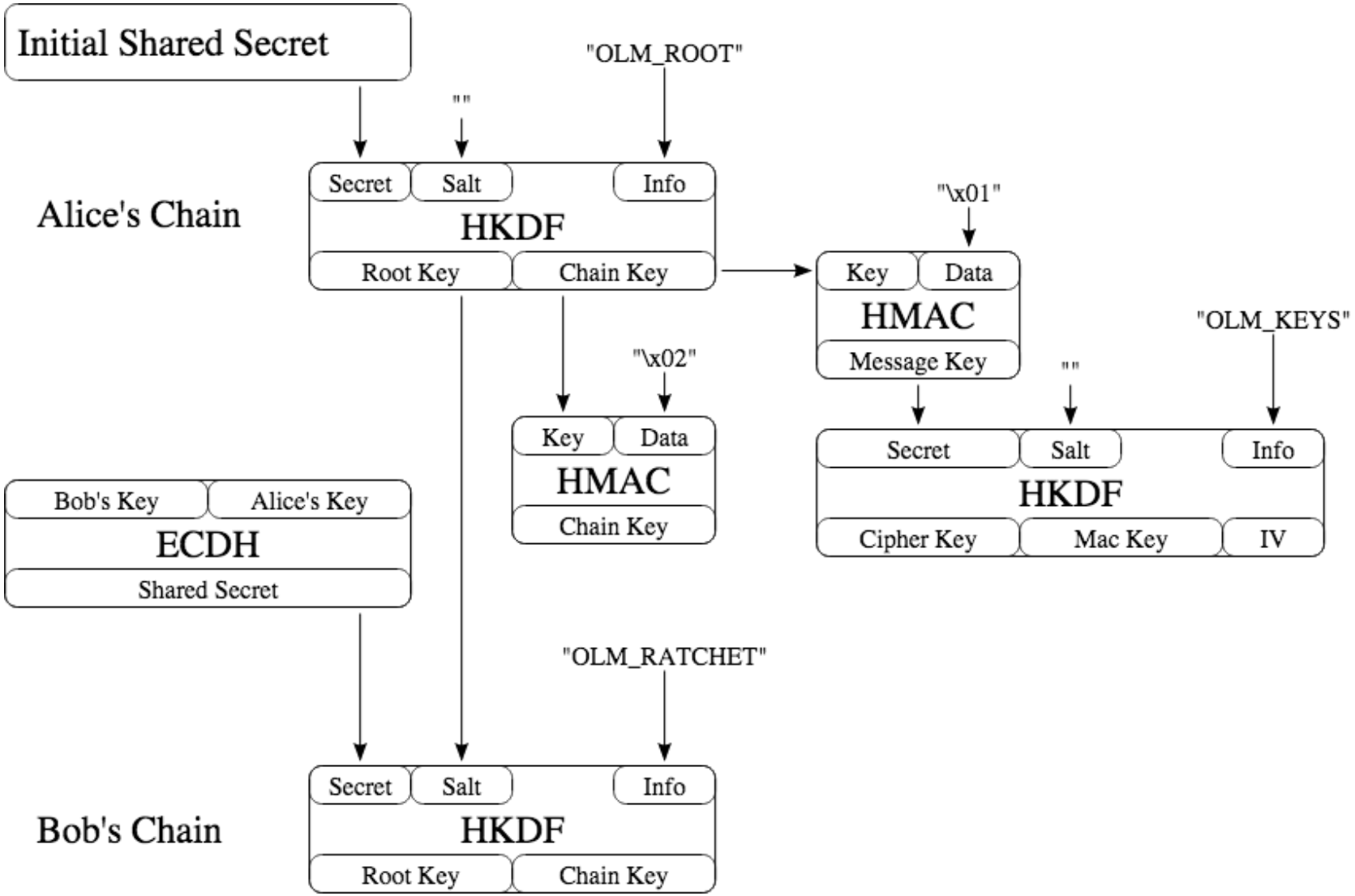
Compute same Initial Shared Secret =
ECDH(Ea, Ib) +
ECDH(Ia, Eb) +
ECDH(Ea, Eb)

Compute same K_0
M_0 = Authenticated decryption of (C_0, K_0)

To respond, B starts new ratchet chain:
Rb_1 = generate random ratchet key pair
New Initial Shared Secret =
ECDH(Ra_0, Rb_1) ← **ECDH Ratchet**

C_0 = Authenticated Encryption of (M, K_0)
Ra_0 = generate random ratchet key
Ja_0 = incremental counter for each hash ratchet advancement

Rb_1, Jb_1, C_1


Initial Shared Secret
"OLM_ROOT"
""
Secret
Salt
Info
HKDF
Root Key
Chain Key
Alice's Chain
"\x01"
Key
Data
HMAC
Message Key
"OLM_KEYS"
"\x02"
""
Key
Data
HMAC
Chain Key
Secret
Salt
Info
HKDF
Cipher Key
Mac Key
IV
Bob's Key
Alice's Key
ECDH
Shared Secret
"OLM_RATCHET"
Secret
Salt
Info
HKDF
Root Key
Chain Key
Bob's Chain

Demo!

http://matrix.org/~markjh/olm/javascript/demo.html

Group chat

- Adds a 3rd type of ratchet, used to encrypt group messages.
- Establish 'normal' 1:1 ratchets between all participants in order to exchange the initial secret for the group ratchet.
- All receivers share the same group ratchet state to decrypt the room.

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Flexible privacy with Olm

- Users can configure rooms to have:
  - No ratchet (i.e. no crypto)
  - Full PFS ratchet
  - Selective ratchet
    - Deliberately re-use ratchet keys to support paginating partial eras of history.
    - Up to participants to trigger the ratchet (e.g. when a member joins or leaves the room)
  - Per-message type ratchets

So, what about protecting metadata?

(i.e. hiding who's talking to who and when?)

Matrix is all about pragmatically fixing today's vendor lock-in problem.

You can't bridge existing networks without exposing who's talking to who.

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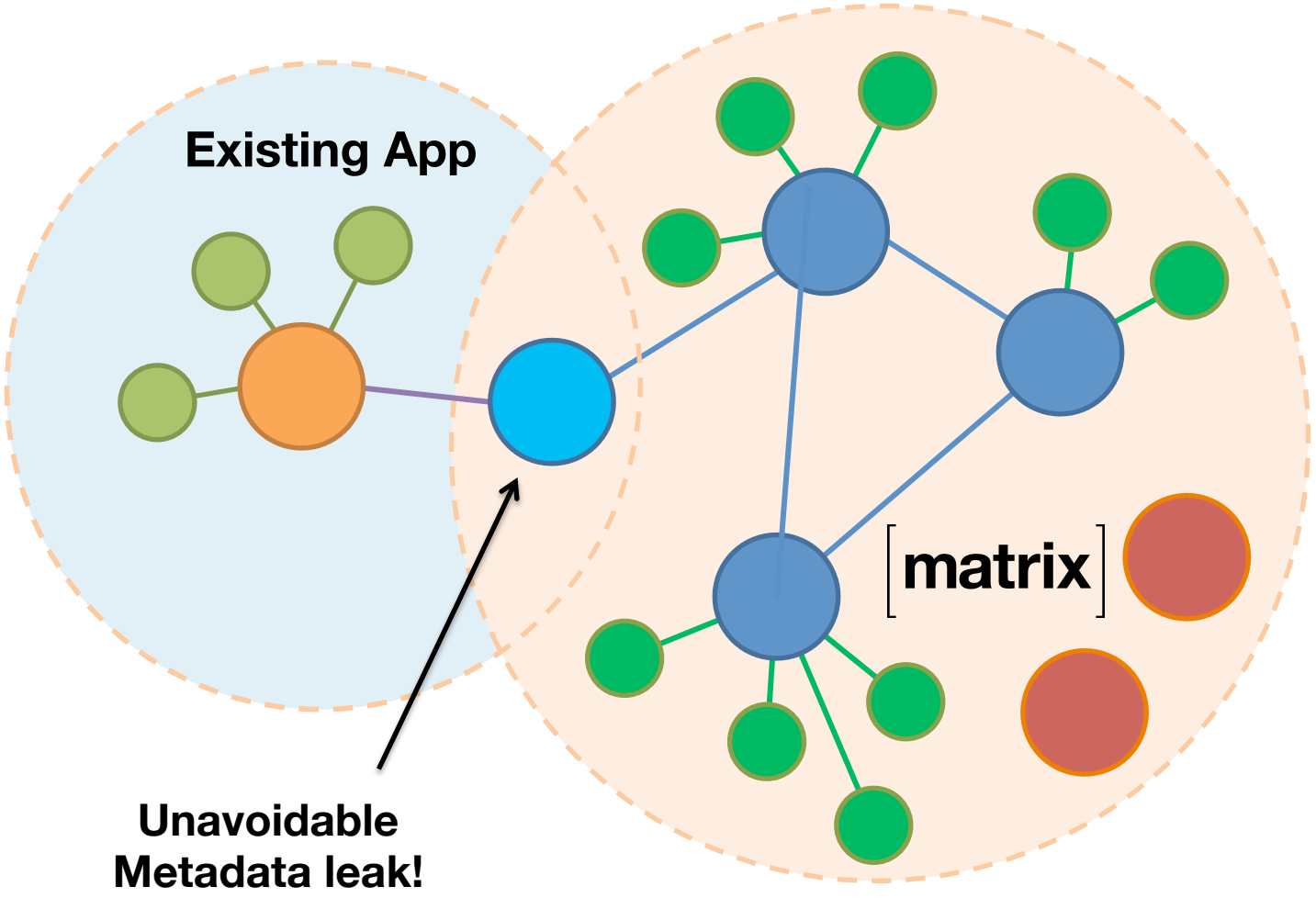
Bridges expose metadata



That said, Matrix also exposes metadata on Home Servers:

Home Servers expose metadata too

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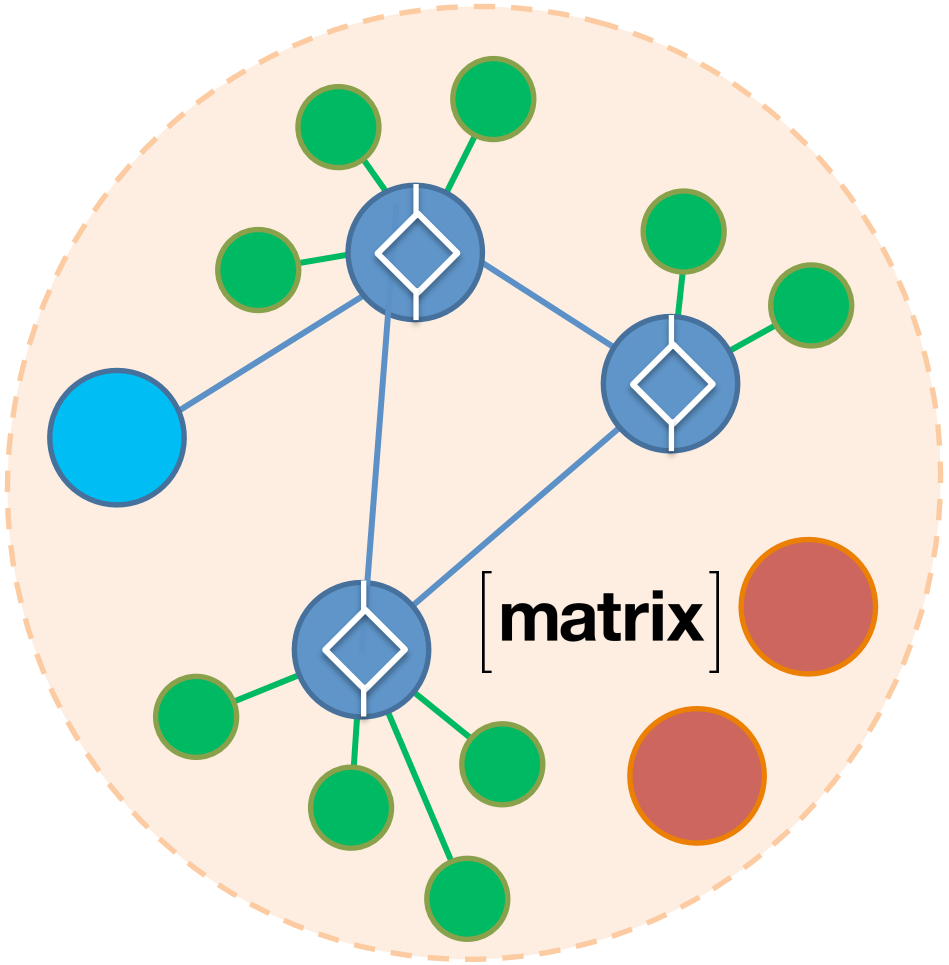


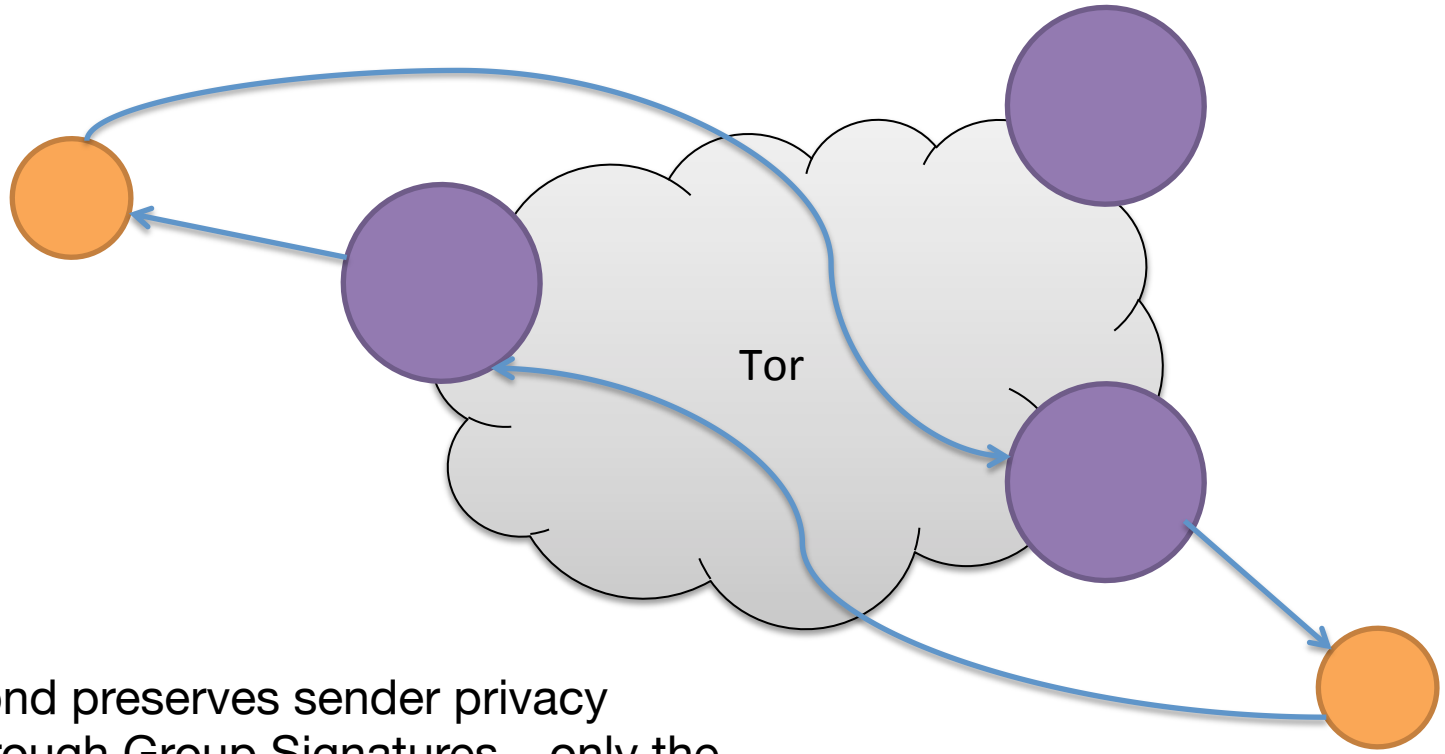
Can we do better?

Apps like Pond show that you can obfuscate metadata quite effectively:

Pond

Pond clients,
storing encrypted
history

Pond servers
(Tor hidden services)



Pond preserves sender privacy through Group Signatures – only the client can decrypt who the message was from.

Matrix was designed to evolve and support future network architectures and privacy strategies.

Thought Experiment: Could Matrix adopt a Pond-like strategy?

- Move home servers onto the client.
- Use pond-style Tor hidden services for store-and-forward of encrypted messages.
- Migrate incrementally from 'classic' DAG federation.

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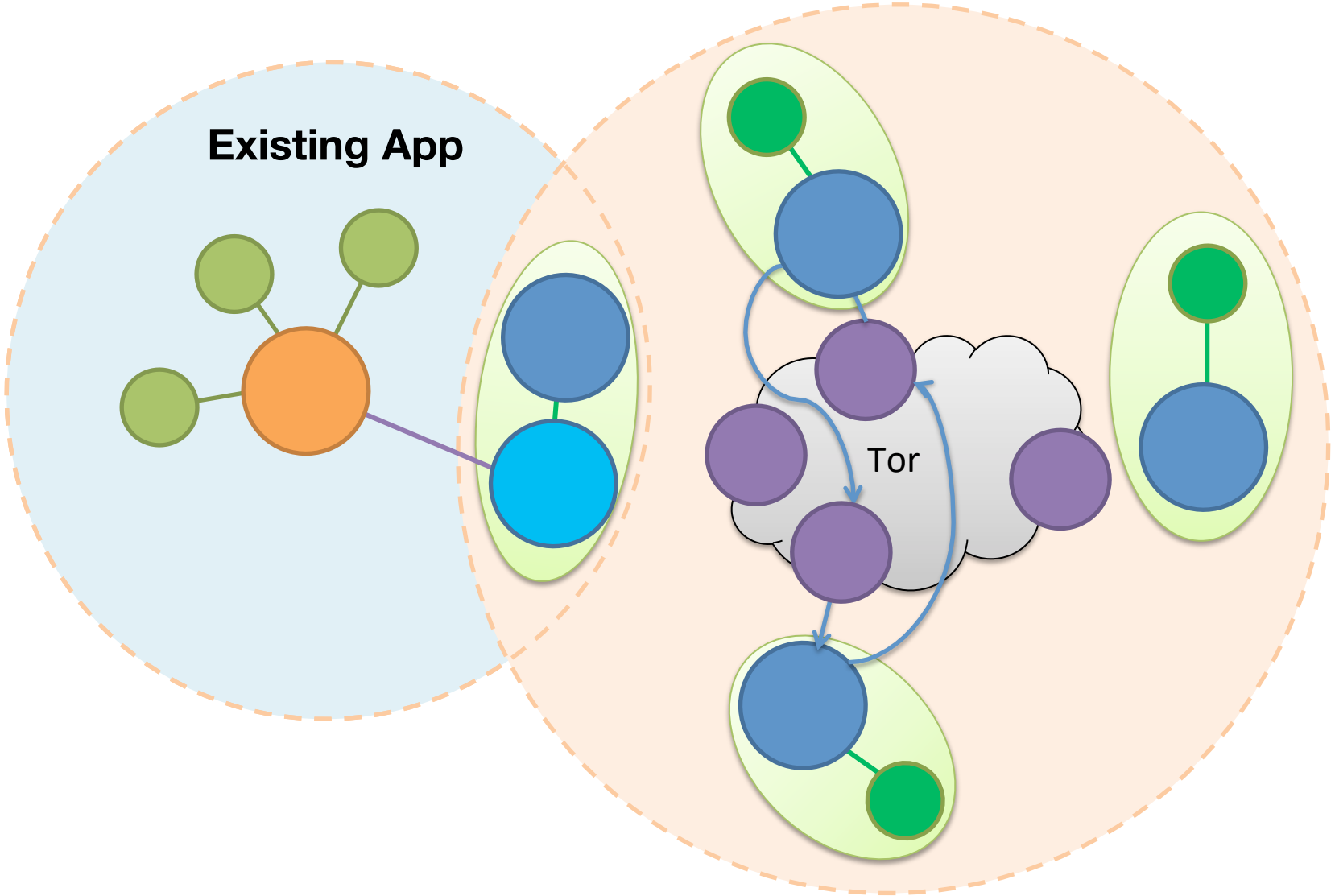
Matrix with Pond strategy



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Advantages over pure Pond

- Supports any and all Matrix clients via the existing standard client-server API
- Supports decentralised conversation history by tunnelling HS federation over Pond
- Supports bridging to other networks via existing Matrix AS API or classic Matrix Federation – at expense of privacy. Mitigated by disabling bridging/federation per-room.

Thank you!

matthew@matrix.org
http://matrix.org
@matrixdotorg

matrix

Federation Design #1

- No single point of control for chat rooms.
- Any homeserver can publish a reference to a chat room (although typically the address is the homeserver of the user who created the room).
- Room addresses look like:

#matrix:matrix.org

(pronounced hash-matrix-on-matrix-dot-org)

- The IP of the matrix.org homeserver is discovered through DNS (SRV _matrix record if available, otherwise looks for port 8448 of the A record).

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Federation Design #2

- When a user joins a room, his HS queries the HS specified in the room name to find a list of participating homeservers via a simple GET
- Messages form a directed acyclic graph (DAG) of chronologicity, each crypto-signed by the origin HS
- The user's HS pulls in messages via GETs from participating HSs by attempting to walk the DAG
- Each HS caches as much history as its users (or admin) desires
- When sending a message, the HS PUTs to participating homeservers (currently full mesh, but fan-out semantics using cyclical hashing in development)

Identity Design

- We don't want to be yet another identity system (e.g. JIDs)
- So we aggregate existing 3rd party IDs (3PID) and map them to **matrix** IDs (MXIDs) by **Identity Servers**, whose use in public is strictly optional.
- And so login and user discovery is typically done entirely with 3rd party IDs.
- ID servers validate 3rd party IDs (e.g. email, MSISDN, Facebook, G+) and map them to MXIDs. MXIDs look like:

@matthew:matrix.org

Security Design #1

- Server-server traffic is mandatorily TLS from the outset
- Can use official CA certs, but automagically self-sign and submit certs to **matrix** ID servers as a free but secure alternative
- Server-client traffic mandates transport layer encryption other than for tinkering
- Clients that support PKI publish their public keys, and may encrypt and sign their messages for E2E security.
- "Well behaved" clients should participate in key escrow servers to allow private key submission for law enforcement.
- End-to-end encryption for group chat is supported through a per-room encryption key which is shared 1:1 between participating members

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Security Design #2

- SPAM is contained by mandating invite handshake before communication
- Invite handshakes are throttled per user
- Homeservers and users may be blacklisted on identity servers
- ID servers authenticating 3PIDs are obligated to mitigate bulk registration of users via CAPTCHAs or domain-specific techniques (e.g. 2FA SMS for MSISDNs)

Application Services: Spec & API

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- Still in development; some early prototypes
- "Passive AS-API" Builds on the client-server API
  - Service registers a URL for inbound events to be PUT to
  - Allows a service to register for traffic on behalf of a namespace of virtual users and virtual rooms
  - Adds "superuser" permissions to subscribe to arbitrary filters of events on the homeserver, and inject arbitrary events
  - Modeled loosely after IRC Services
- Also: Active AS API for intercepting inbound events on a HS, and Storage API for exposing existing conversation DBs to Matrix via a HS.

AS Example: Matrix/SMS Gateway

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- matrix.org runs a homeserver.
- Matrix/SMS gw AS is registered to the homeserver, masquerading for the 'sms.matrix.org' domain.
- @447968722968:sms.matrix.org routes to the homeserver from anywhere in Matrix, which passes events for *:sms.matrix.org through to the AS
- Matrix/SMS Gateway then relays via SMS aggregators to send SMS to +447968722968
- The reverse path is symmetrical, with the Matrix/SMS AS injecting events into the HS on behalf of @447968722968:sms.matrix.org

AS Example: Matrix/SIP Gateway

matrix

- Similarly, AS can implement a SIP gateway, posing as a range of virtual matrix users.
- Events such as 'm.call.invite' and 'm.call.candidates' are PUT to the AS by the HS
- AS converts directly into SIP signalling (reINVITEing to advertise new ICE candidates)
- Media flows out-of-band to Matrix as typical WebRTC SRTP.
- We've already written a basic Matrix/Verto gateway (using client-service API – see matrix.org/blog)

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Why not XMPP?

- We used to use XMPP (ejabberd, OpenFire, Spectrum, psyced, Psi, Pidgin, ASmack, Spark, XMPP.Framework)
- We built an alternative because:
  - Single server per MUC is single point of control
  - Synchronised history is a very 2nd class citizen
  - Stanzas aren't framed or reliably delivered
  - XMPP stacks are not easy to implement in a web environment
  - Jingle is complicated and exotic
  - XML is needlessly verbose and unwieldy
  - The baseline feature-set is too minimal
  - JIDs haven't taken off like Email or MSISDNs
  - Not designed for mobile use cases (e.g. push; low bw)
  - Well documented spam and identity/security issues
  - ejabberd