Decentralised Communication: The challenge of balancing interoperability and privacy.

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

(real soon now)
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 Impl**s
  - **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

- Matrix Web Console
- Matrix iOS Console
- Android Console
- MatrixKit (iOS)
- matrix-ios-sdk
- matrix-js-sdk
- matrix-angular-sdk

The Matrix Specification (Client/Server API)

- Synapse (Reference Matrix Server)
- Matrix Application Services
- Other Servers and Services
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\rn=0-658458 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
m.call.invite
m.call.candidate
[more candidates events]
User answers call
[media flows]
<------ m.call.answer
<------ m.call.hangup

Callee
The client-server API

To persist some MIDI:

curl -XPOST -d '{
    "note": "71",
    "velocity": 68,
    "state": "on",
    "channel": 1,
    "midi_ts": 374023441

{ "event_id": "ORzcZn2" }
The server-server API

curl -X POST -H 'Authorization: X-Matrix origin=matrix.org,key="898be4...",sig="j7JXfIcPFDWL1pdJz..."' -d '{
  "ts": 1413414391521,
  "origin": "matrix.org",
  "destination": "alice.com",
  "prev_ids": ["e1da392e61898be4d2009b9fece5325"],
  "pdus": [{
    "age": 314,
    "content": {
      "body": "hello world",
      "msgtype": "m.text"
    },
    "context": "!fkILCTRBTthN5gkP: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/7EZbjHFhIFgXj6HGoSI+j7JXfIcPFDWL1pdJz+JJPMHTDIZRha7SoJ7lq7UM+CnhNAayHwZsUY3Ag"
      }
    }
  }]
} https://alice.com:8448/_matrix/federation/v1/send/916d630ea616342b42e98a3be0b74113
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)
• ...


A trivial application service

```python
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()
```
Matrix Bridging with ASes
Current Progress

- Funded May 2014
- Launched alpha Sept 2014
- Entered beta Dec 2014
- Stable v0.9 Beta May 2015
- July 2015: v1.0 release?!
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.
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 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 (K₀) from chain key (HMAC)
Derive new chain key ← hash ratchet
M₀ = Message plaintext
C₀ = Authenticated Encryption of (M₀, K₀)
Ra₀ = generate random ratchet key pair
Ja₀ = incremental counter for each hash ratchet advancement

Ia, Ea, Eb, Ra₀, Ja₀, C₀
Alice  

Bob  

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

Compute same K₀
M₀ = Authenticated decryption of (C₀, K₀)

To respond, B starts new ratchet chain:
Rb₁ = generate random ratchet key pair
New Initial Shared Secret = 
ECDH(Ra₀, Rb₁) ← ECDH Ratchet

C₀ = Authenticated Encryption of (M, K₀)
Ra₀ = generate random ratchet key
Ja₀ = incremental counter for each hash ratchet advancement

Rb₁, Jb₁, C₁
Demo!

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

• Adds a 3\textsuperscript{rd} 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.
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.
Bridges expose metadata

Unavoidable Metadata leak!
That said, Matrix also exposes metadata on Home Servers:
Home Servers expose metadata too
Can we do better?

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

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

Pond servers
(Tor hidden services)

Pond clients,
storing encrypted history
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.
Matrix with Pond strategy
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!

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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).
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
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 3PIIDs are obligated to mitigate bulk registration of users via CAPTCHAs or domain-specific techniques (e.g. 2FA SMS for MSISDNs)
Application Services: Spec & API

- 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

- 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

- 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).
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 2\textsuperscript{nd} 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