Multi-Provider DNS

Why it is important, where it is now and how to make it simpler and safer

Johan Stenstam Erik Bergström Leon Fernandez

Swedish Internet Foundation

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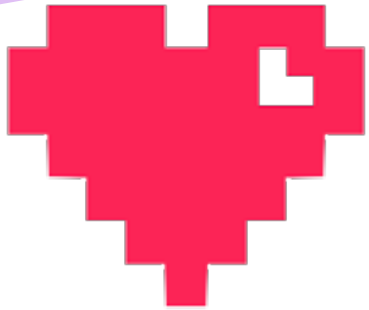

The Real Problem

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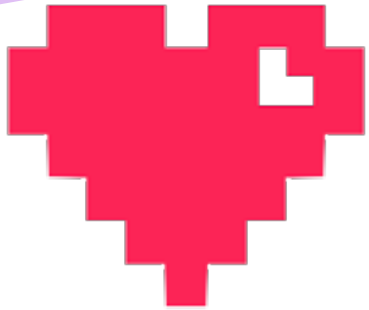
Multi-Provider Is Already Best Current Practice

Many zones — including many of the most important ones — already use multiple DNS providers. This is best current practice for resilience and availability.



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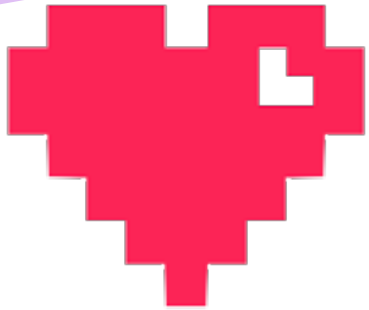

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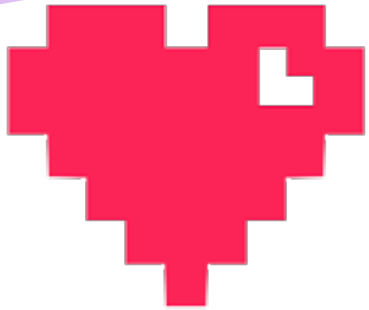

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The perceived need is limited:
"How many zones really need multiple *signing* providers?"

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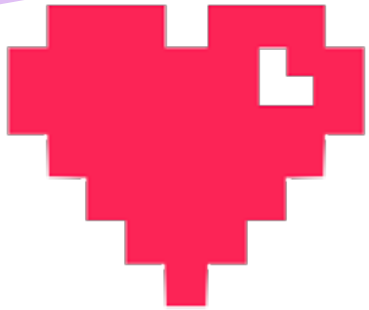

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The perceived need is limited:
"How many zones really need multiple *signing* providers?"

But this framing misses the point.

The hard part is not the signing — it is *synchronizing sensitive zone data across organizational boundaries*.

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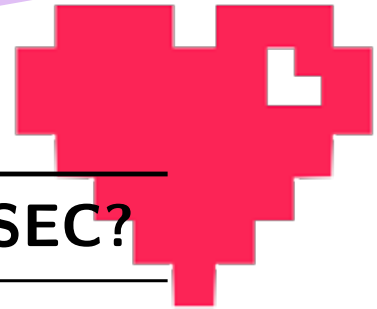
It's the Synchronization, Not the Signing



Consider what providers need to coordinate:

Record	**Why**	**DNSSEC?**
NS	Each provider's nameservers	No
In-bailiwick glue	Each provider's NS addresses	Yes
DNSKEY	Each provider's signing keys	Yes
CDS/CSYNC	DS/NS updates to parent	Yes

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Same trust problem. Same timing problem.
Same need for confirmed delivery.

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If we solve the synchronization problem for multi-provider, we get multi-signer almost for free.

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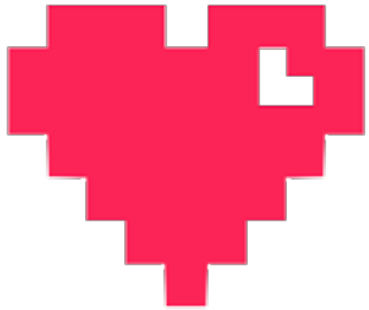

Why Has This Been Difficult?

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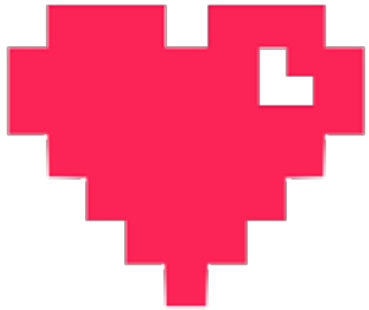
Three Hard Sub-Problems



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Who is authorized to contribute which records?

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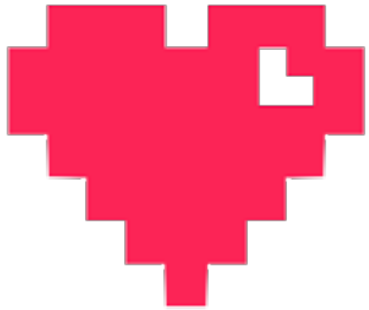

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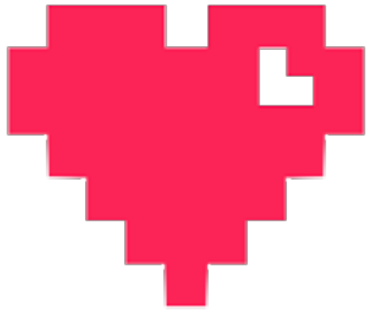

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3. No standard infrastructure

There is no standard way to discover peers, establish secure channels, or exchange structured messages between DNS providers.

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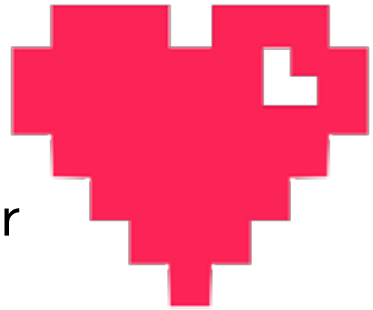
Current Operational Reality



Manual

Operators coordinate via email, tickets, or ad hoc scripts. Error-prone and slow.

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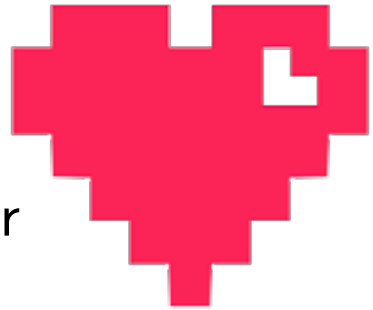

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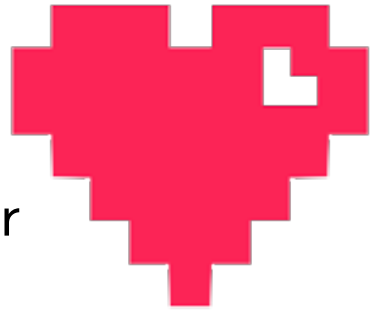

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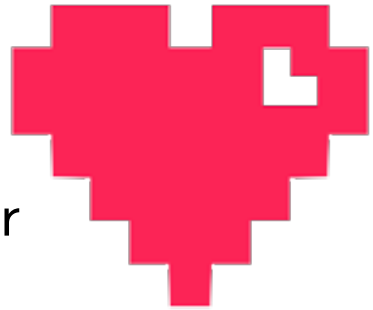

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There is no standard, interoperable way to automate multi-provider DNS synchronization.

This is the gap we are trying to fill.

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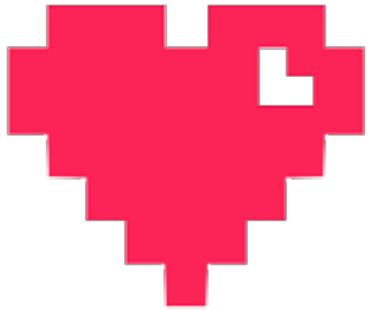

Architecture

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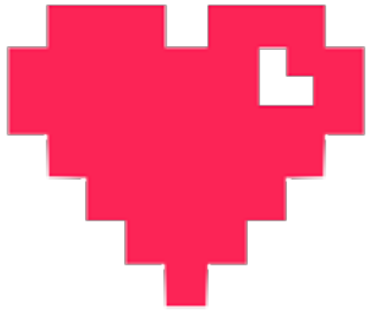
The Workflow



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   — *"I want multi-provider sync for this zone"*

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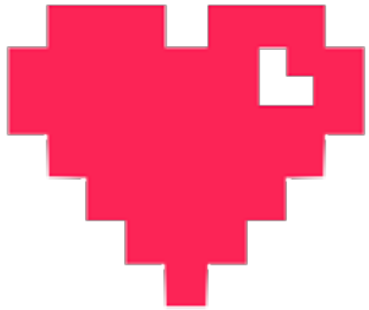

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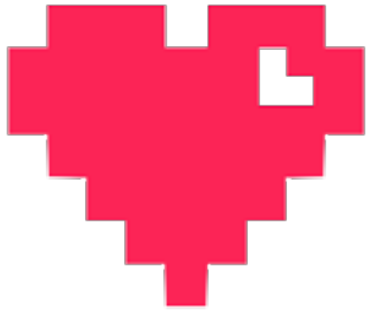

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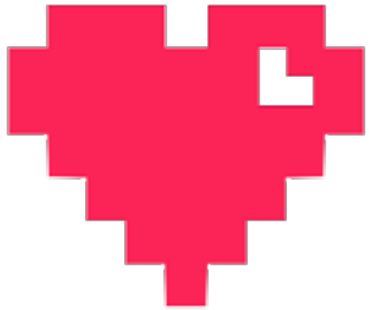

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4. Synchronized management of the zone begins

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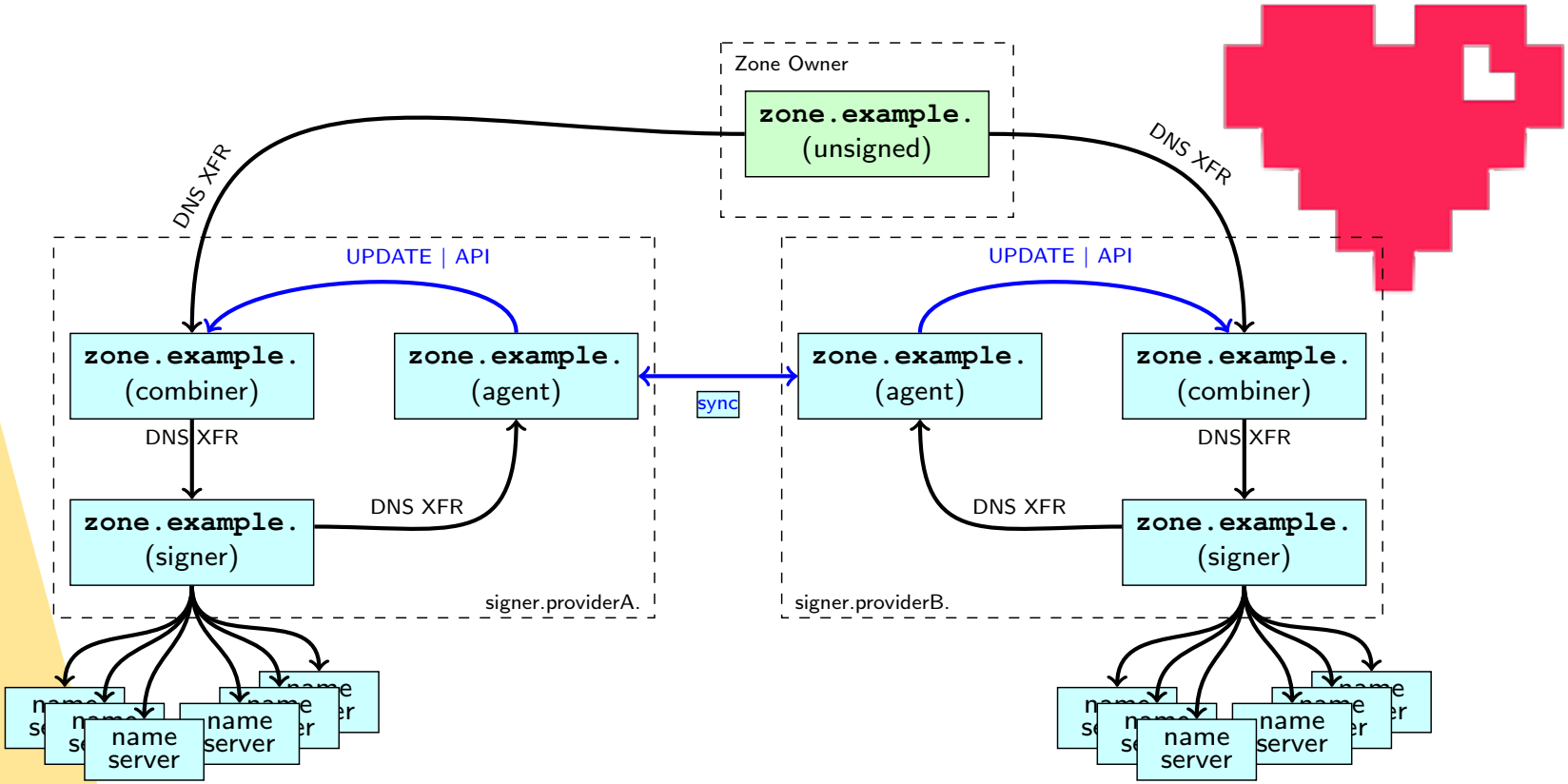
Roles


Zone Owner
zone.example.
(unsigned)
DNS XFR
DNS XFR
UPDATE | API
UPDATE | API
zone.example.
(combiner)
zone.example.
(agent)
sync
zone.example.
(agent)
zone.example.
(combiner)
DNS XFR
DNS XFR
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zone.example.
(signer)
zone.example.
(signer)
signer.providerA.
signer.providerB.
name server
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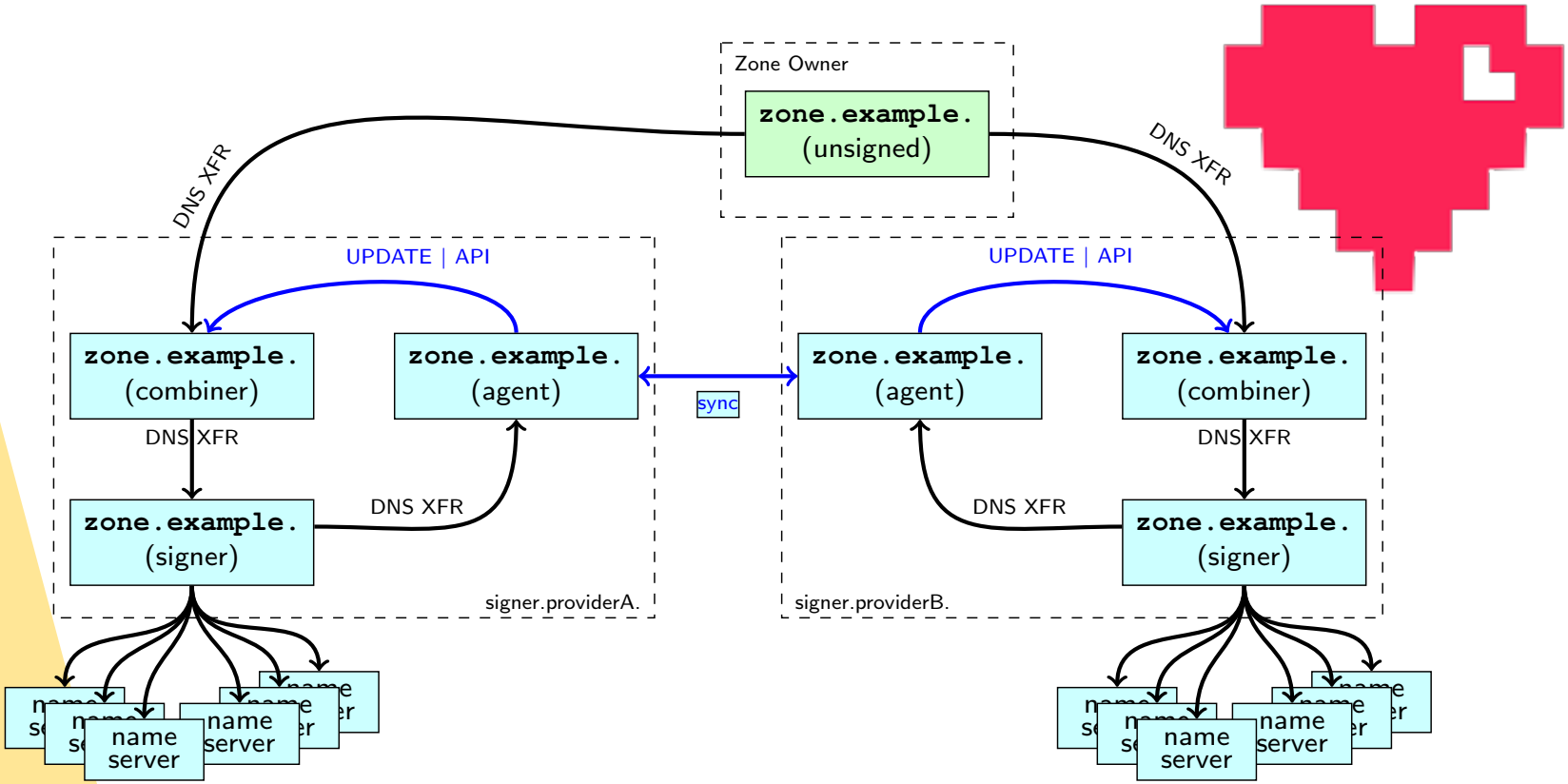
Roles



Four roles, clear separation of concerns:

- **Zone Owner**: Authoritative source of the unsigned zone
- **Agents**: Per-provider sync (peer-to-peer, discovered via HSYNC)
- **Combiners**: Merge and validate contributions from all agents
- **Signers**: DNSSEC-sign the combined zone

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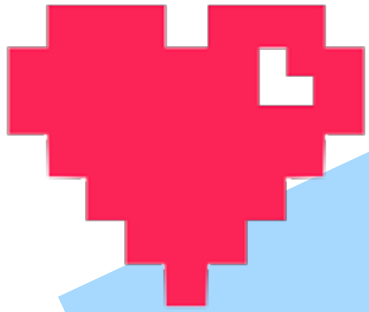
The HSYNC and HSYNCPARAM RRsets



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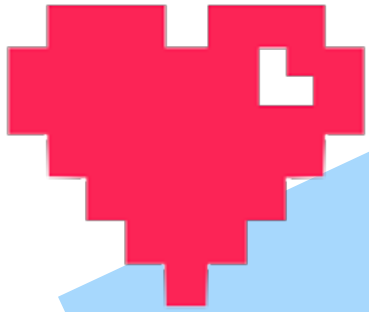

The HSYNC and HSYNCPARAM RRsets

Two records, one source of truth

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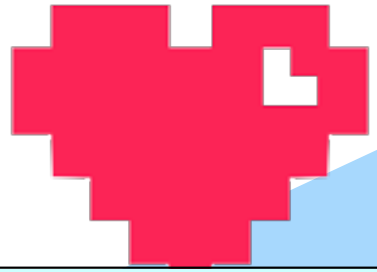
HSYNC + HSYNCPARAM at the Zone Apex



The zone owner publishes one HSYNC record per agent at the zone apex. Each record identifies one provider:

```
customer.zone. IN HSYNC ON alpha agent.alpha.example. .
customer.zone. IN HSYNC ON bravo agent.bravo.example. .
customer.zone. IN HSYNC ON echo  agent.echo.example.  alpha
```

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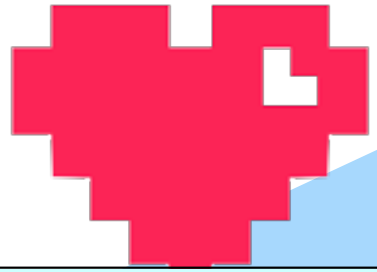

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customer.zone. IN HSYNC ON alpha agent.alpha.example. .
customer.zone. IN HSYNC ON bravo agent.bravo.example. .
customer.zone. IN HSYNC ON echo  agent.echo.example.  alpha
```

Four HSYNC RDATA fields:

- **State**: **`ON`** or **`OFF`** (onboarded vs. being removed)
- **Label**: short tag for this provider (referenced by HSYNCPARAM)
- **Identity**: the provider's FQDN (starting point for agent discovery)
- **Upstream**: label of the provider this one pulls from (**`.`** = manual setup)

The HSYNC RRset identifies the involved parties.

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HSYNC + HSYNCPARAM at the Zone Apex

HSYNCPARAM completes the picture: a single record at the apex carrying the zone-wide multi-provider policy:

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customer.zone. IN HSYNC ON bravo agent.bravo.example. .
customer.zone. IN HSYNC ON echo  agent.echo.example.  alpha
customer.zone. IN HSYNCPARAM servers="alpha,bravo,echo" signers="alpha,bravo" nsmgmt="agent"
```

HSYNCPARAM keys (extensible, SVCB-style):

- **servers**: providers (labels) authorized to **serve** the zone
- **signers**: providers (labels) authorized to **sign** the zone
- **nsmgmt**: **`owner`** or **`agent`** — who manages NS records
- **parentsync**: **`owner`** or **`agent`** — who handles parent sync

HSYNC + HSYNCPARAM maps each provider to the zone policy via labels and roles.

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From HSYNC to Secure Communication

1. Agent analyzes the HSYNC RRset for each zone it serves
   If it finds itself listed ⇒ this zone requests sync
   HSYNCPARAM provides the zone policy (signing, NS mgmt, ...)
   ↓
2. Extract remote agents' Identity fields from the HSYNC records
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3. Look up each remote agent's transport endpoint
   (URI → SVCB records for details)
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4. Look up the remote agent's public key (JWK or TLSA)
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5. Handshake: establish authenticated channel
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Adding or removing a provider = updating the HSYNC RRset.
Agents detect the change and act automatically.

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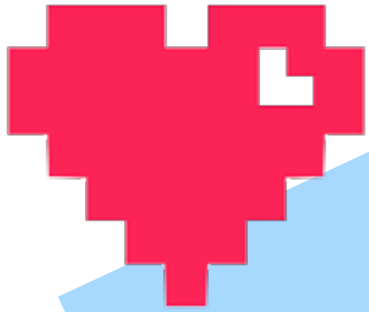
Validation

Validation: The Combiner

Architectural decision: *one single point* where all remote contributions are validated before being applied.



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The combiner ensures that contributions are safe and correct — nothing has gone wrong, nothing is malicious:

- Standard validation rules (defined by the protocol)
- Optional manual approval (likely needed by some providers)

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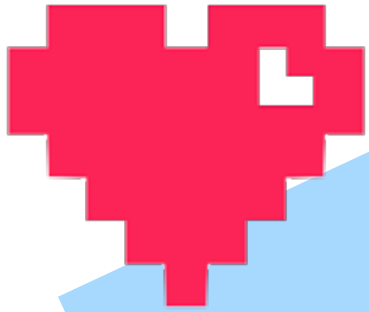

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Each provider decides for themselves what validation requirements their customers require.

Every contribution gets a per-RR confirmation back to the originating agent: accepted or rejected, with reasons.

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Confirmed Delivery

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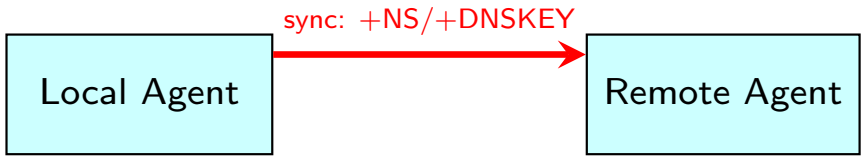

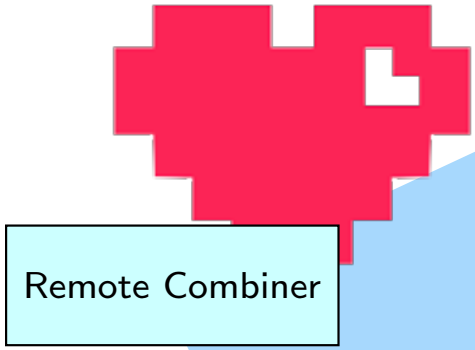

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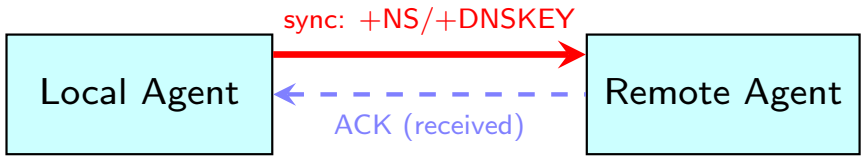

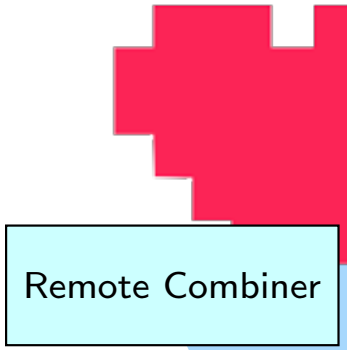

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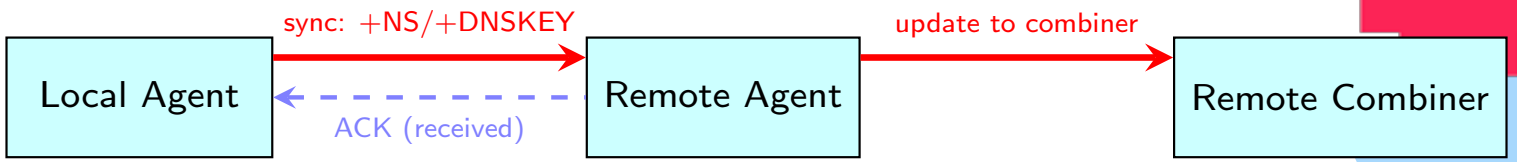

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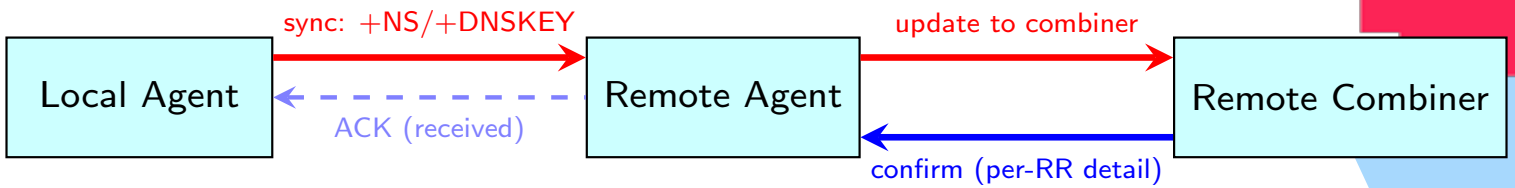

Confirmed Delivery

Confirmed Delivery

Two-step confirmation:

- **Step 1**: Immediate ACK (prevents retransmission)
- **Step 2**: Final per-RR confirmation from combiner (accepted/rejected with reasons)

The originating agent *knows* its contribution was accepted and published. This is what makes coordinated DNSKEY rollovers safe.

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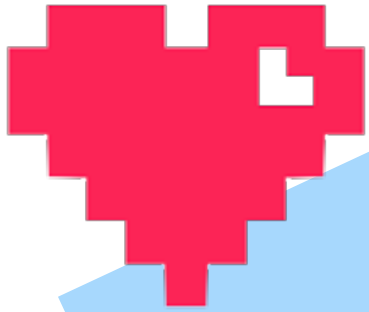
Self-Healing



All sync operations are *idempotent*:

- **SYNC**: send my contributions to a peer.
  If the peer already has the same data: nothing changes.
  Safe to repeat after restart, reconnection, or timeout.

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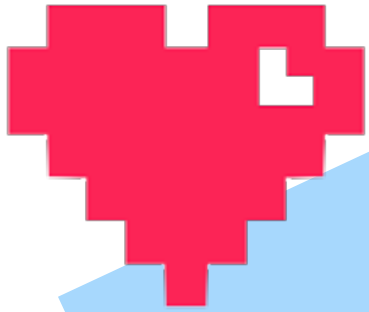
Self-Healing



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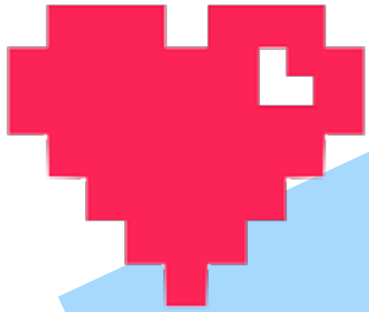

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- Any agent can recover full state from its peers.
  No special recovery logic. This is also how a *new provider bootstraps*: send RFI, get up to date.

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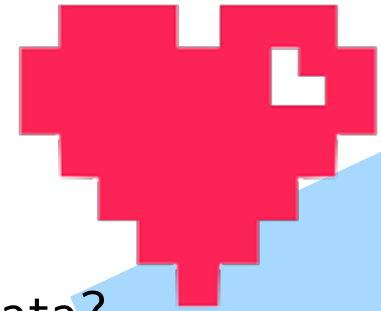
The Hard Part: Synchronization



A challenge has been the development of a model for distributed synchronization of DNS data.

- Which providers should be able to contribute what data?
- Where should the gates be? At the sender or at the receivers?
- How should the synchronization be designed to allow arbitrary restarts and also recovery from crashes?
- How should responsibility for parent synchronization be agreed upon (assuming it is wanted)?
- How does a multi-provider setup affect the DNSSEC key rollover state-machine?
- Etc.

There are still details to iron out. But there is a working prototype, and all the issues do seem to have good answers.

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Prototype Status

Prototype Status

What works, what doesn't, what is next

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What Works Today

The prototype ("TDNS") implements the full architecture:

Capability	**Status**
Agent discovery via HSYNC	Working
Secure messaging (encrypted + signed)	Working
NS synchronization across providers	Working
DNSKEY synchronization (lifecycle)	Working
Combiner policy + namespace protection	Working
Two-step confirmed delivery	Working
Reliable delivery (retry until confirmed)	Working
Idempotent sync + RFI	Working
Agent restart & bootstrap from peers	Working
Combiner persistence (survives restart)	Working
CLI management tools	Working

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What Doesn't Work Yet

Gap	Description
CDS/CSYNC notifications to parent	Prototype working, but not yet fully integrated.
Automated key rollover	DNSKEY sync works across multi-provider; full KSK rollover is still only single-provider
Transport	DNS-based transport complete; REST API transport incomplete
Provider addition/removal	Orderly works; disorderly needs more testing
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These are engineering tasks, not research problems.
The hard architectural questions have been answered.

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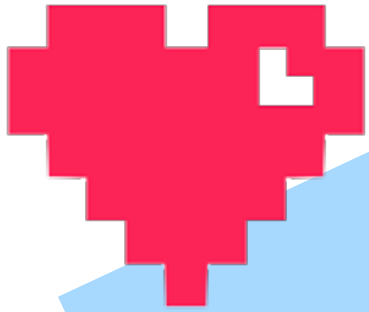
What Is Next

Near-term:

- Automated DNSKEY rollover (end-to-end)
- Wrap-up parent synchronization
- Automatic setup of zone transfers
- Stress testing and fault injection



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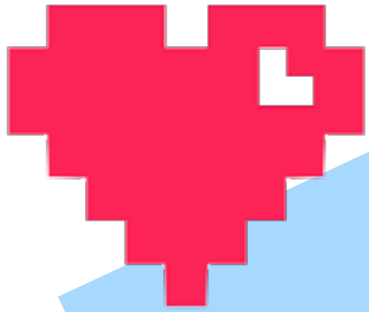
- Operational tooling (monitoring, auditing)



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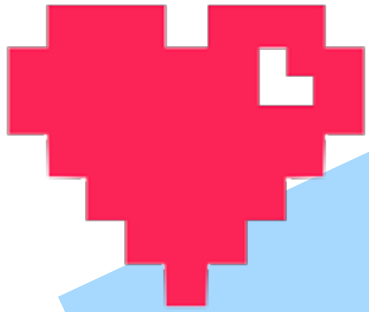
Longer-term:

- Standardization of the sync protocol (IETF)
- Making multi-provider DNS *easier* to deploy than single-provider DNS is today



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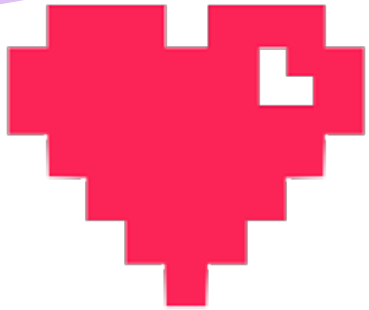
Summary



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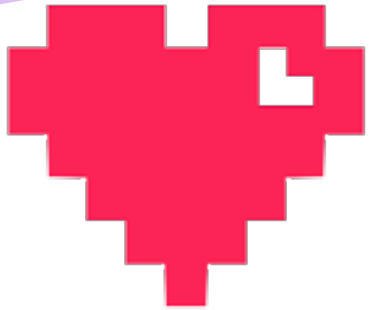

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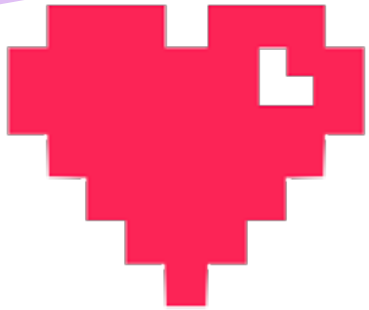

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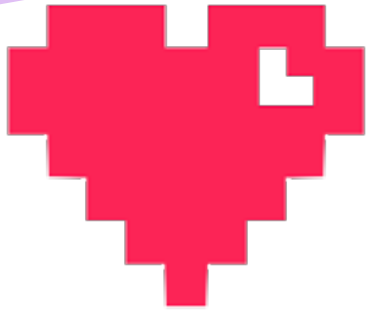

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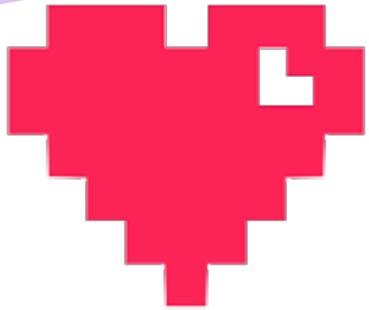

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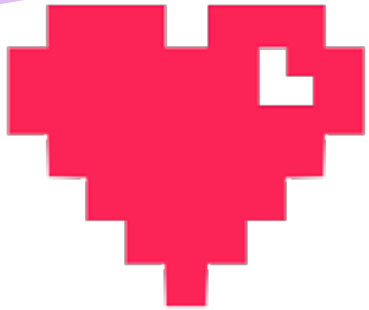

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Goal: make multi-provider DNS *operationally feasible* for everyone, not just the largest operators.

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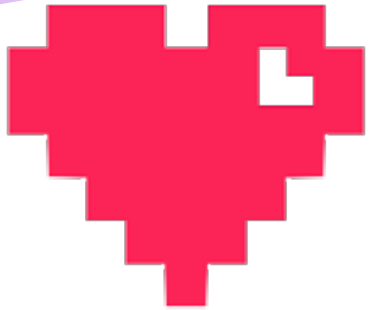

Questions?

Contact `johan.stenstam@internetstiftelsen.se`

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