STIR/SHAKEN: A Looming Privacy Disaster

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University of Michigan

Presented by Josh Brown

Robocalls & Fraud

We've been trying to reach you about your car's extended warranty!

You've won a free cruise to the Bahamas!

This is Microsoft Technical support.

Scammers & Fraud

MARKETS

How phone scammers tricked Americans out of

Robocall Scams Are Costing Us Billions — And Millennials Are A Prime Target

Scam Robocalls Forecast to C

n This Year

Phil Muncaster

UK / EMEA News Reporter

Email Phil

Robocall scams surge to 85 billion globally

According to Hiya

robocall spam has surged around the world and each coun

its own unique fa

Americans Receive Two Billion Spam Calls Per Month

Americans lost $29.8 billion to phone scams alone over the past year

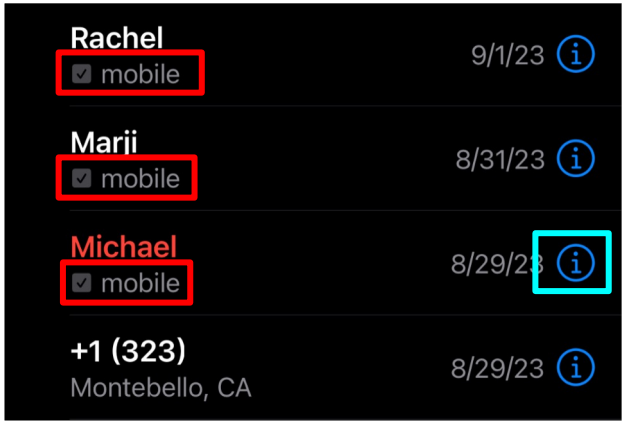
Published Tue, Jun 29 2021•9:00 AM EDT

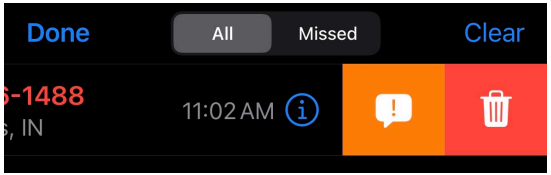
Megan Leonhardt

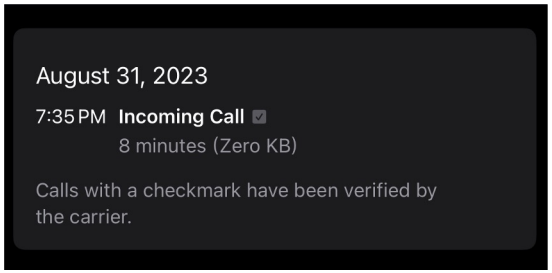
@MEGAN_LEONHARDT

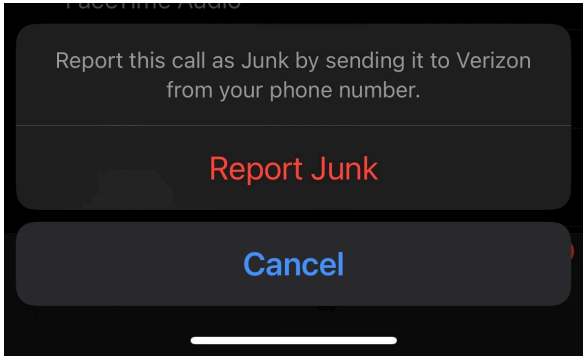
SHARE

Familiar Screens









STIR/SHAKEN

Public Law 116–105
116th Congress

An Act

Dec. 30, 2019
[S. 151]

To deter criminal robocall violations and improve enforcement of section 227(b) of the Communications Act of 1934, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

Pallone-Thune Telephone Robocall Abuse Criminal Enforcement and Deterrence Act
47 USC 609 note.

SECTION 1. SHORT TITLE.

This Act may be cited as the "Pallone-Thune Telephone Robocall Abuse Criminal Enforcement and Deterrence Act" or the "Pallone-Thune TRACED Act".

Trump signs the TRACED Act, the first federal anti-robocall law

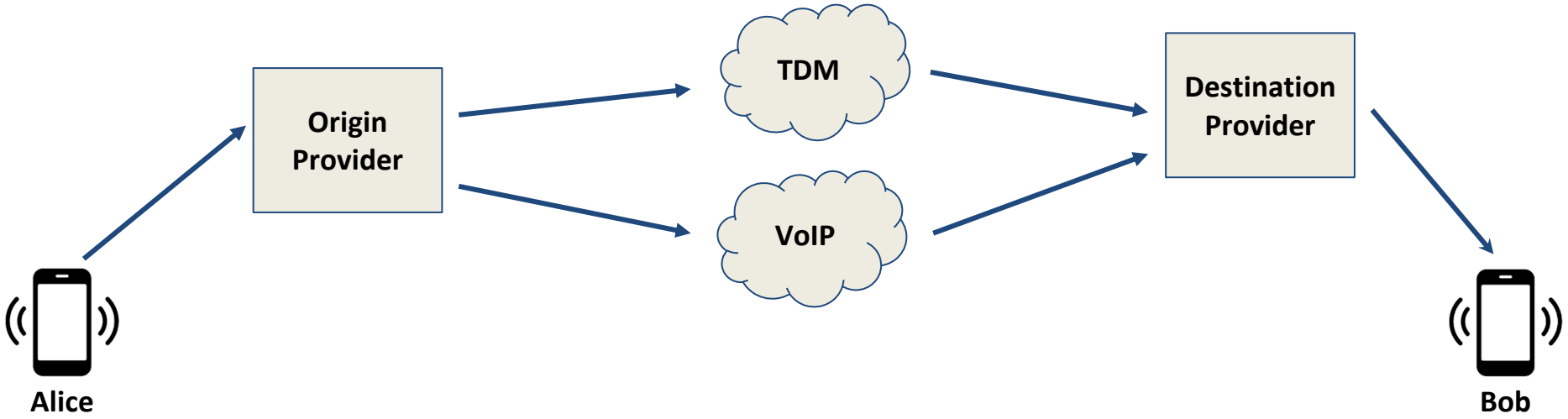
The law implements new consumer protections, gives more teeth to law enforcement efforts and takes other steps to combat unwanted robocalls.

Results Overview

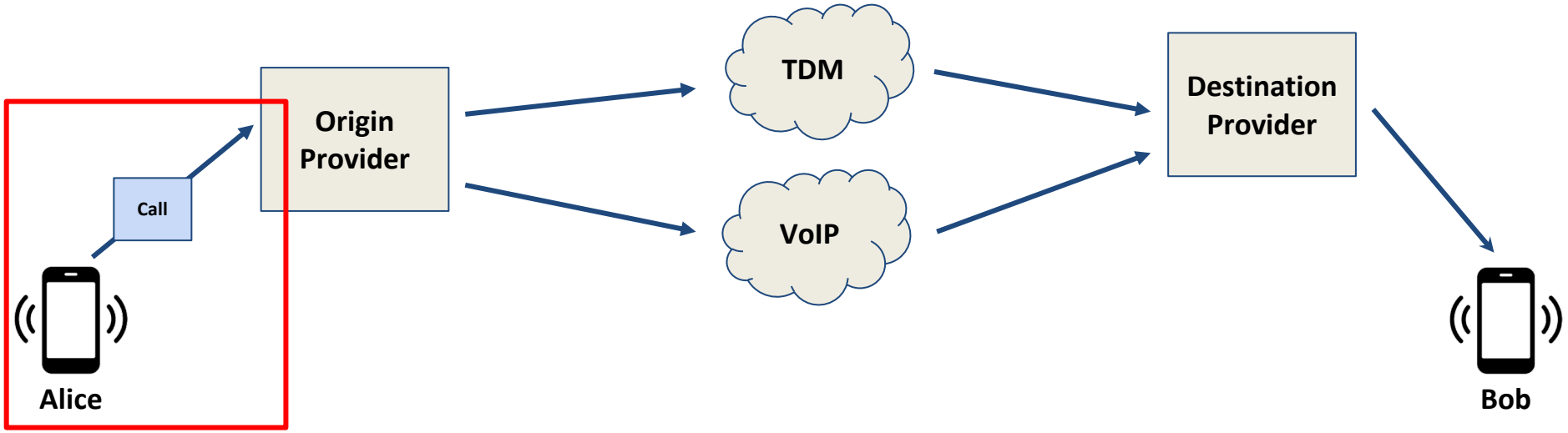
- Flaws
  - Non-repudiable metadata
  - New metadata leakage
  - Numerous PKI issues
- Survey (n=29)
  - Conducted using FCC’s Robocall Mitigation Database
- Solutions
  - Blind signing (and verifying)
  - Deniable signatures
  - Improved protocol for non-internet calls

Background

Telecom Ecosystem: How to make a phone call?



Telecom Ecosystem: How to make a phone call?



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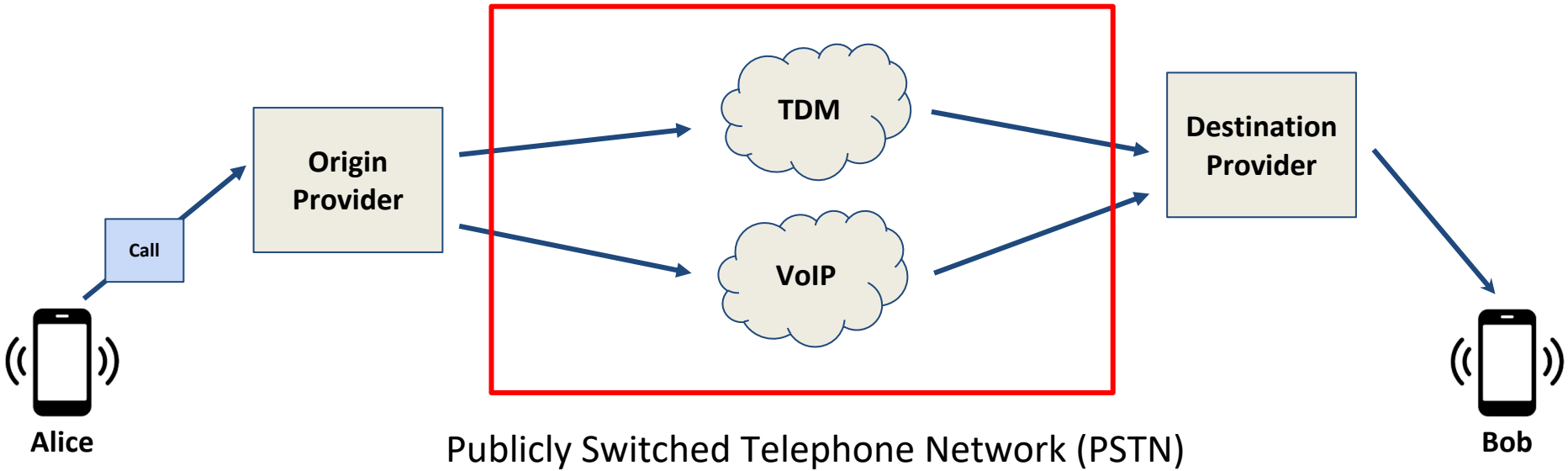

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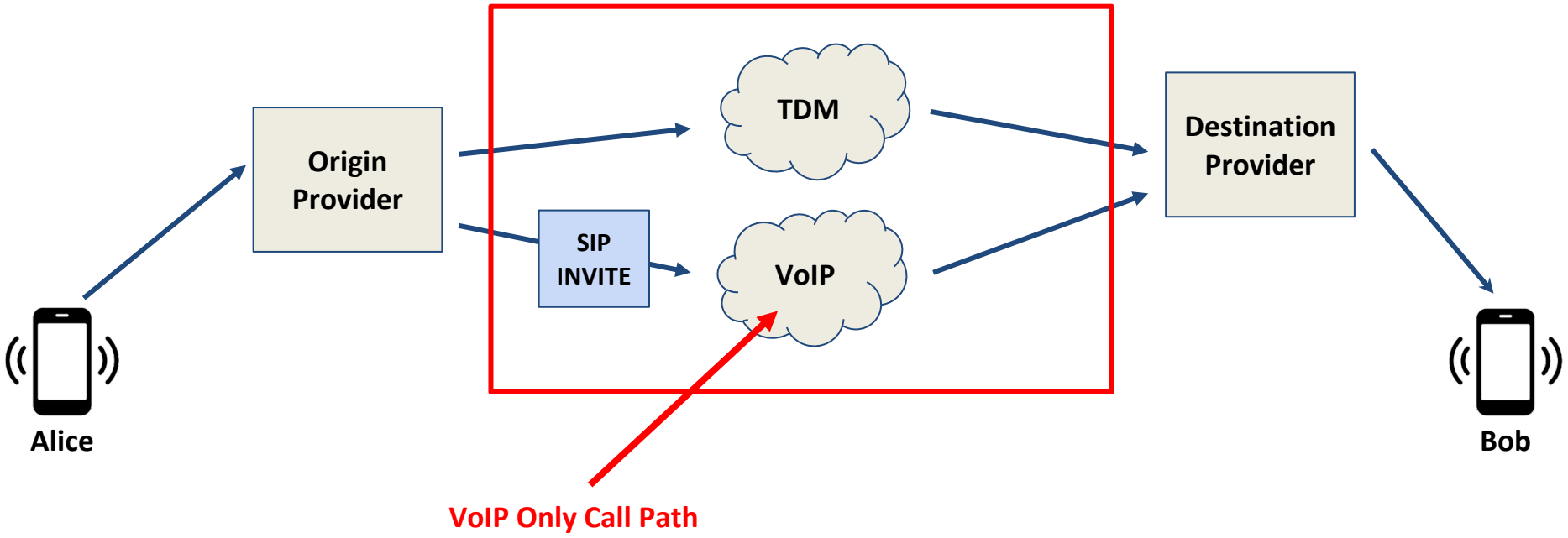

Traditional SIP INVITE Example

```
INVITE sip:+14155552222@example.att.com SIP/2.0
Via: SIP/2.0/UDP 1.2.3.4:5060;branch=z9hG4bK776asdhds
Max-Forwards: 70
To: "Bob" <sip:+14155552222@example.att.com>
From: "Alice" <sip:+14155551111@example.pstn.verizon.com>;tag=1
Call-ID: a84b4c76e66710
CSeq: 1 INVITE
Contact: "Alice" <sip:+1415555111@1.2.3.4:5060>
Content-Length:
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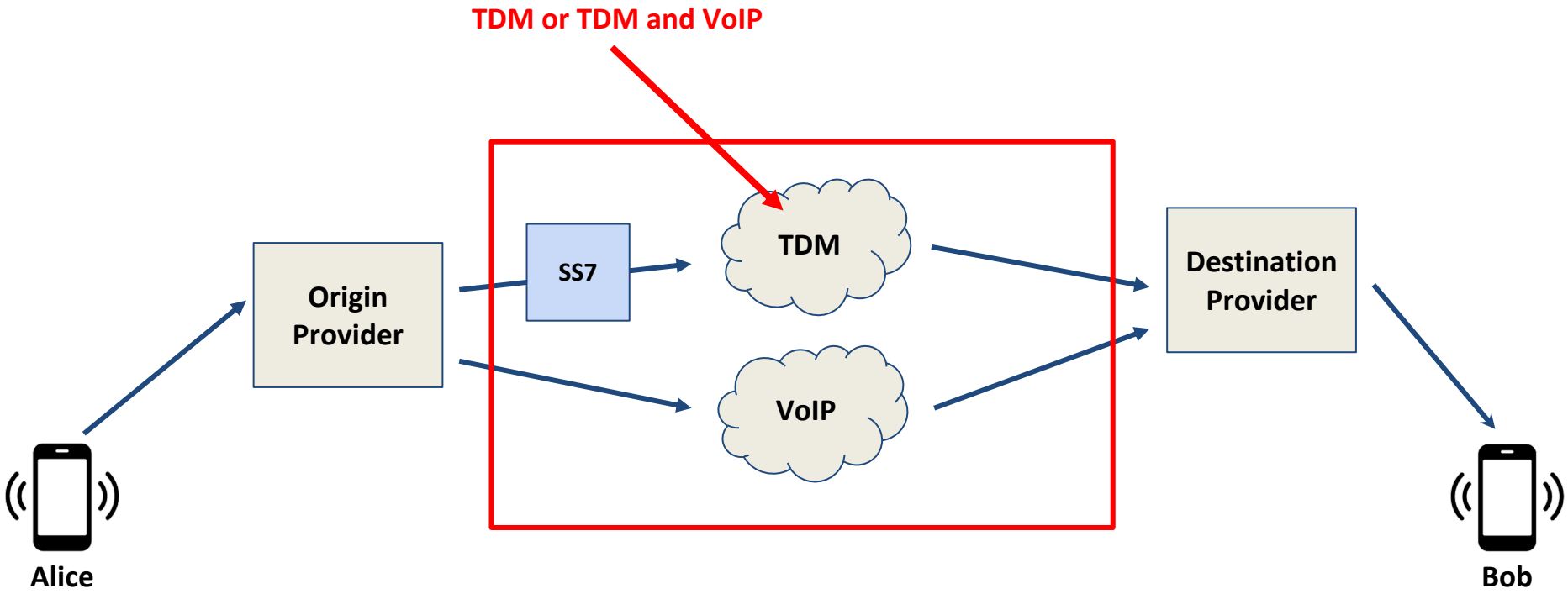
CSeq: 1 INVITE
Contact: "Alice" <sip:+14155551111@1.2.3.4:5060>
Content-Length:
```

Trivial to spoof.

Leads to spam calls

Telecom Ecosystem: How to make a phone call?



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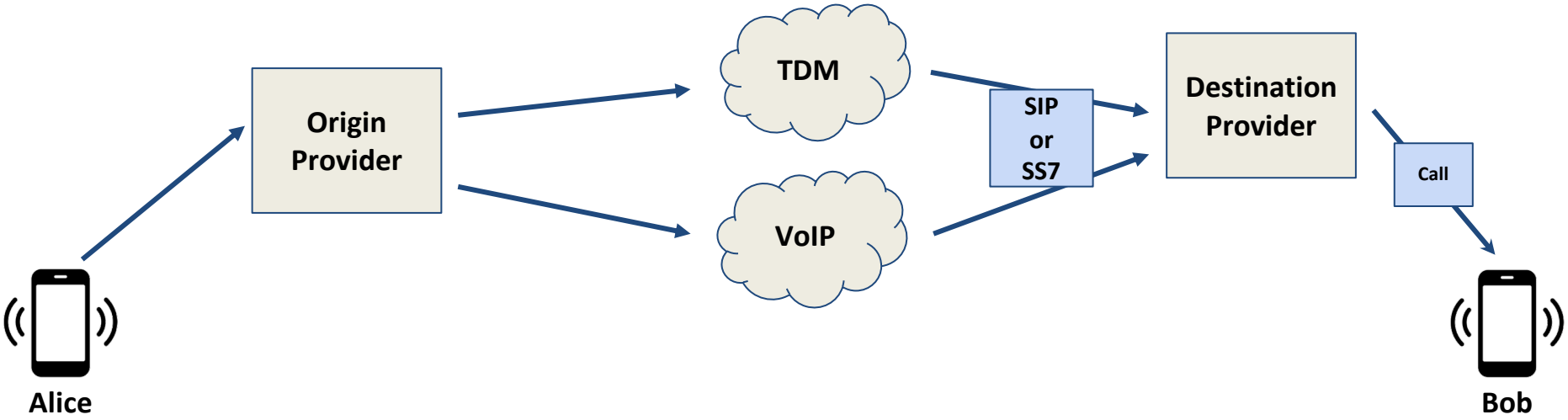
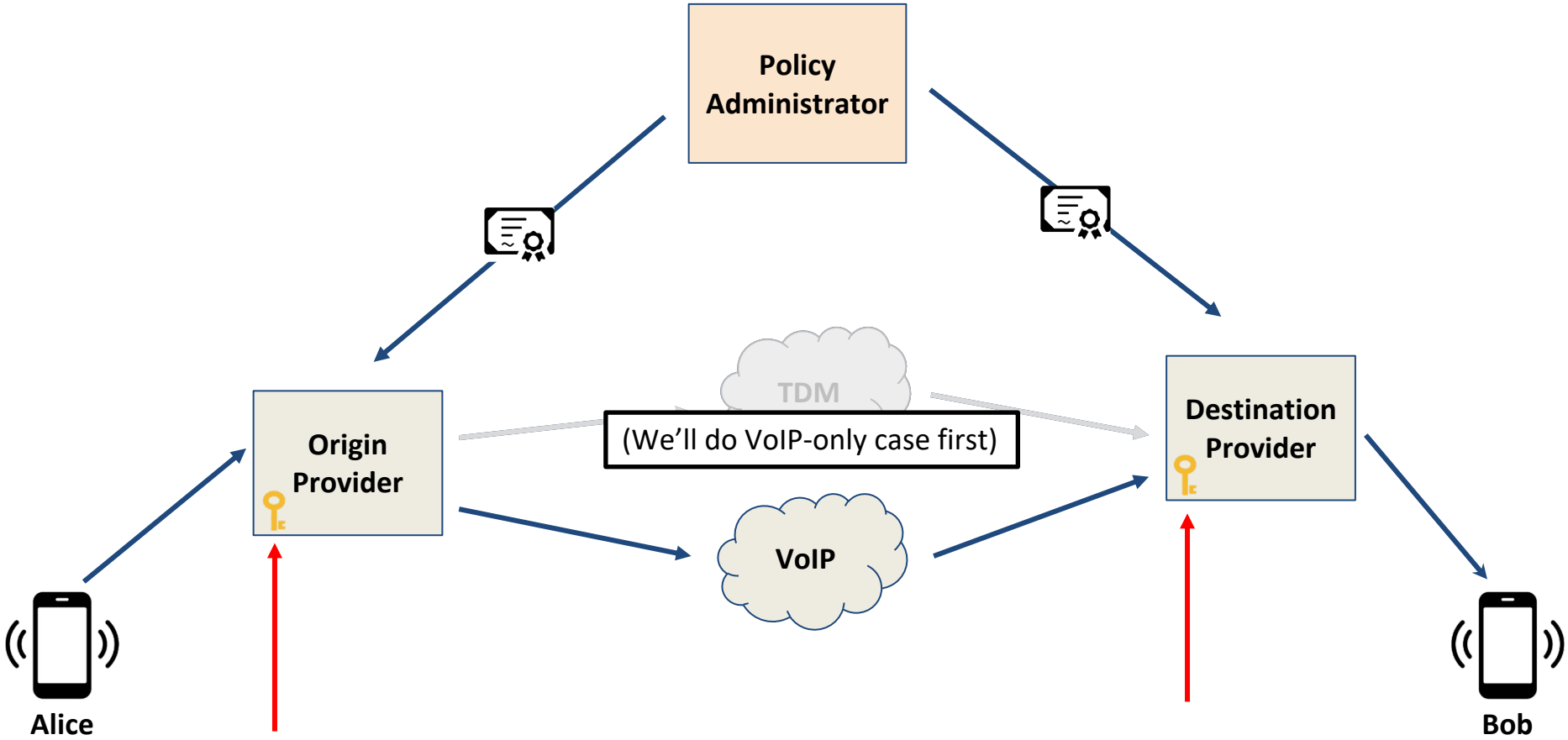


STIR/SHAKEN

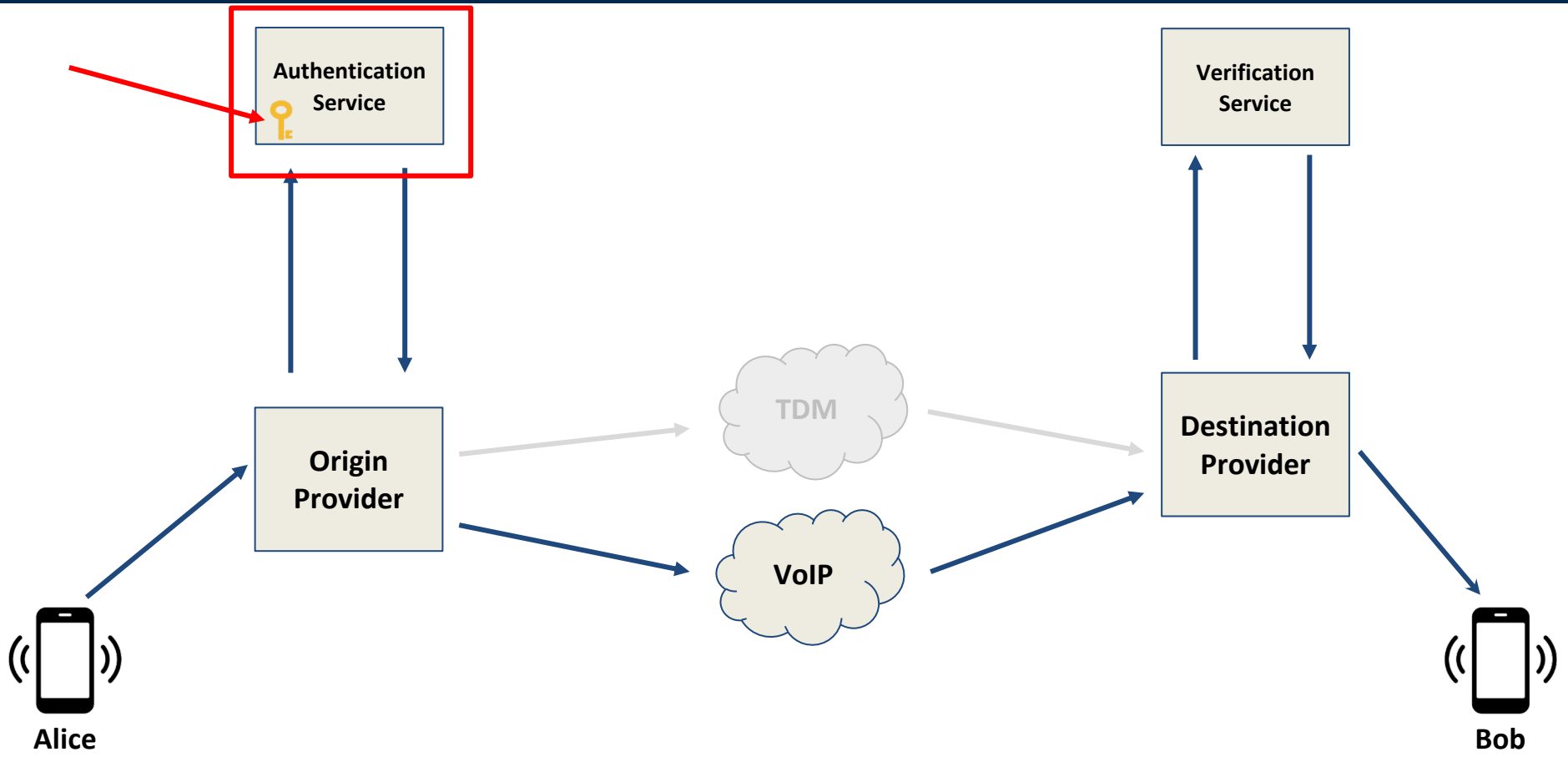
- Telecoms sign call metadata = “attestation” about caller
- Creates a new PKI for providers
- **NOT** identity system for callers
- Reporting mechanisms help punish negligent telecoms
- ~900 telcos participating, 37% of all calls signed (Feb. ‘24)

Source: https://transnexus.com/blog/2024/shaken-statistics-february/

STIR/SHAKEN: Architecture



STIR/SHAKEN: Architecture



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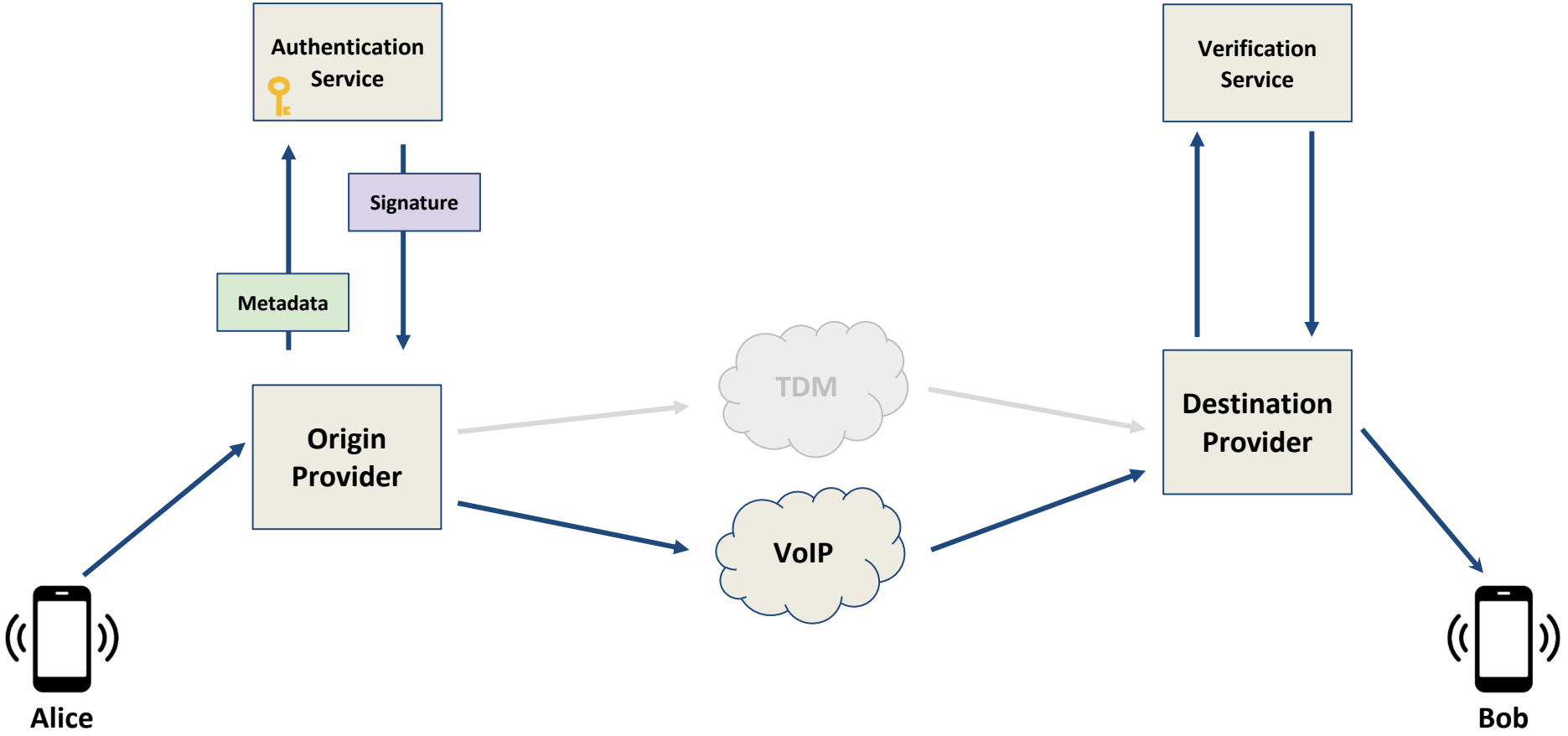
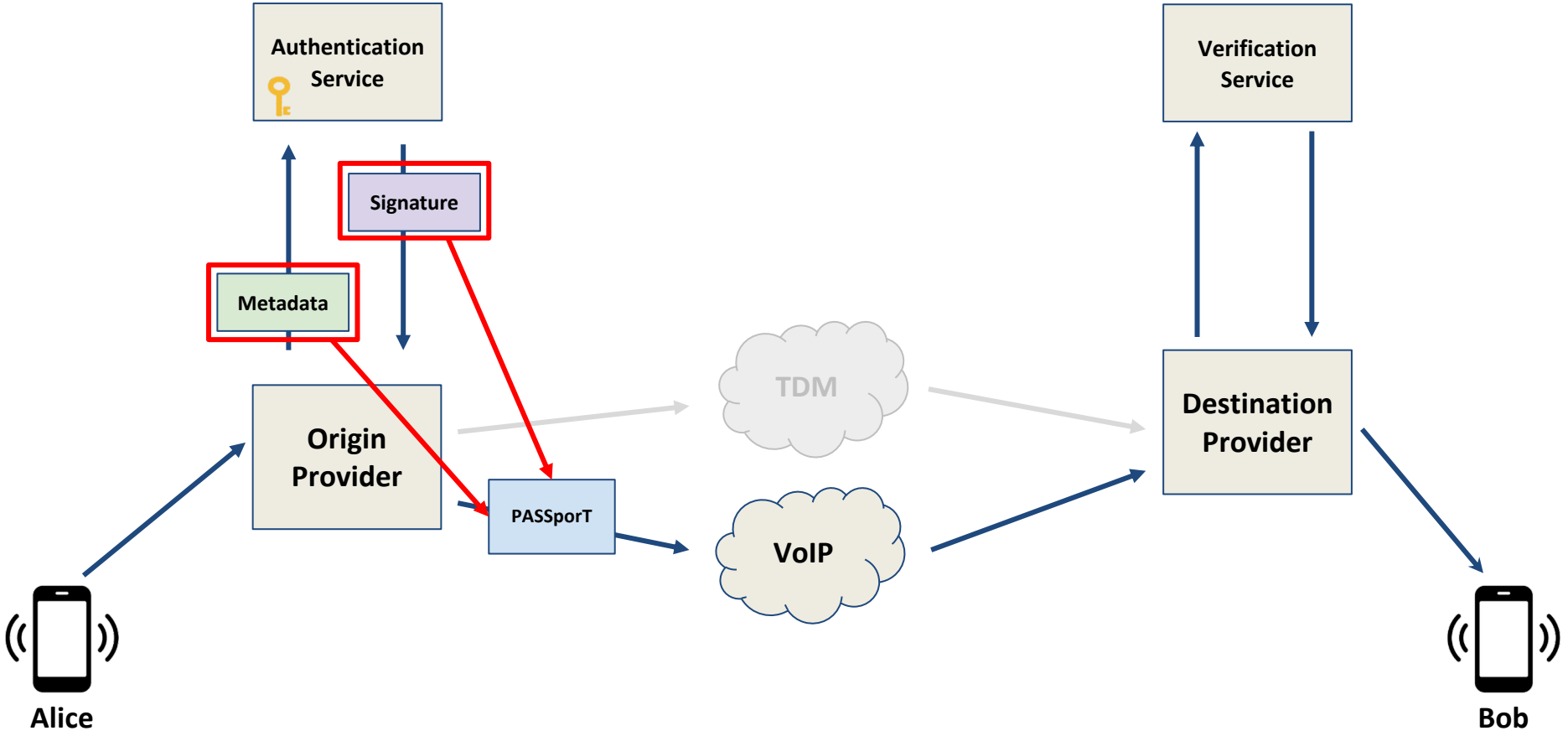


STIR/SHAKEN: Architecture



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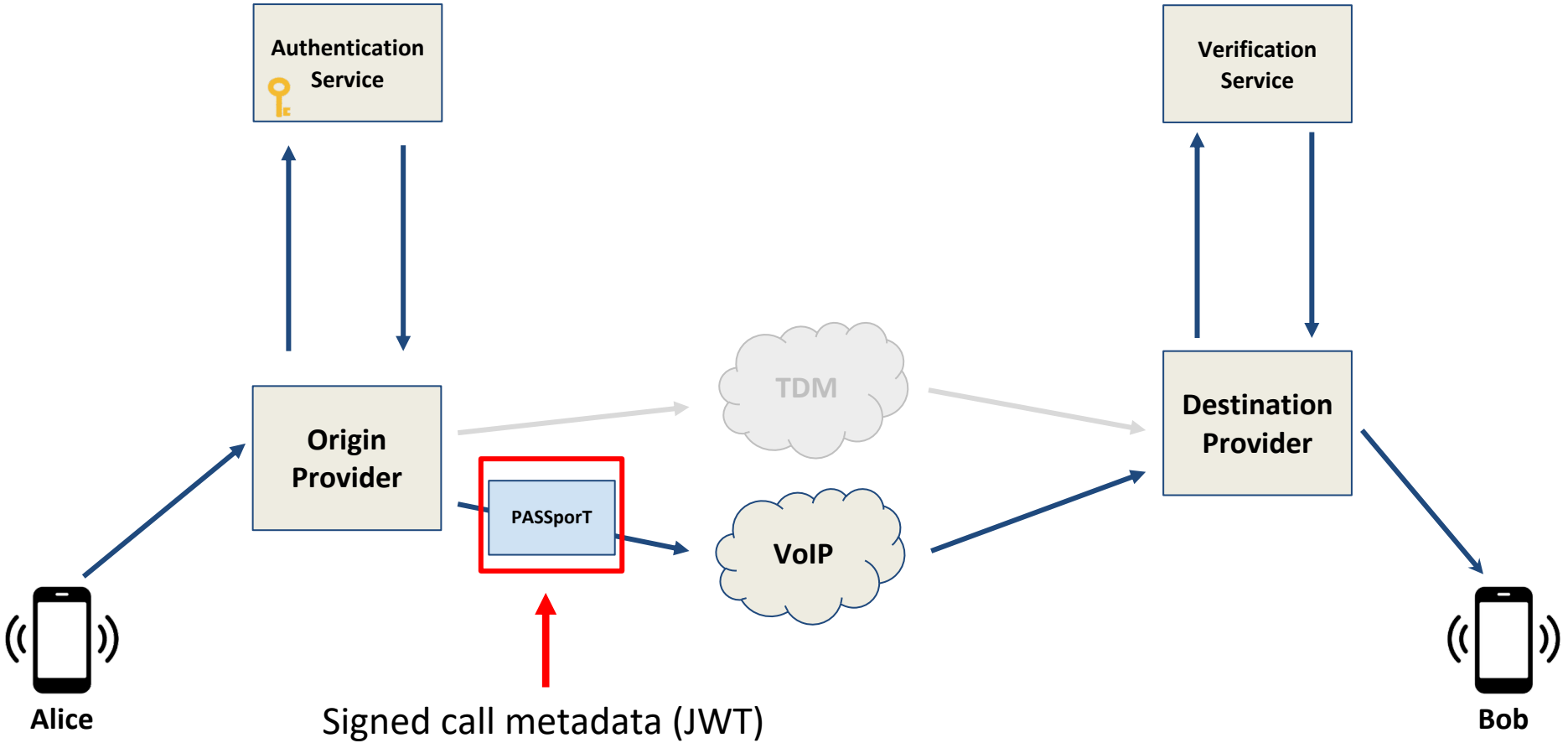
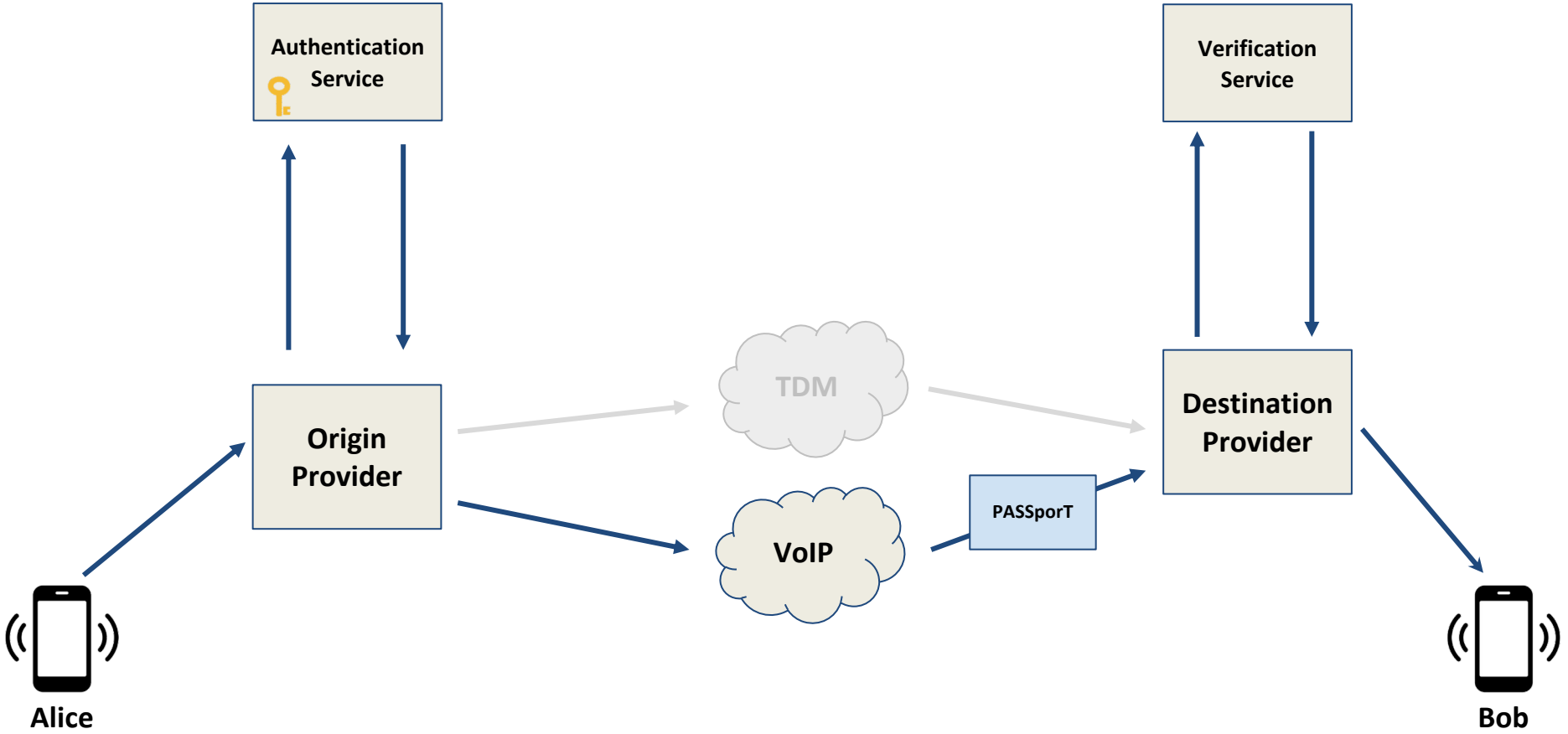


STIR/SHAKEN: Architecture



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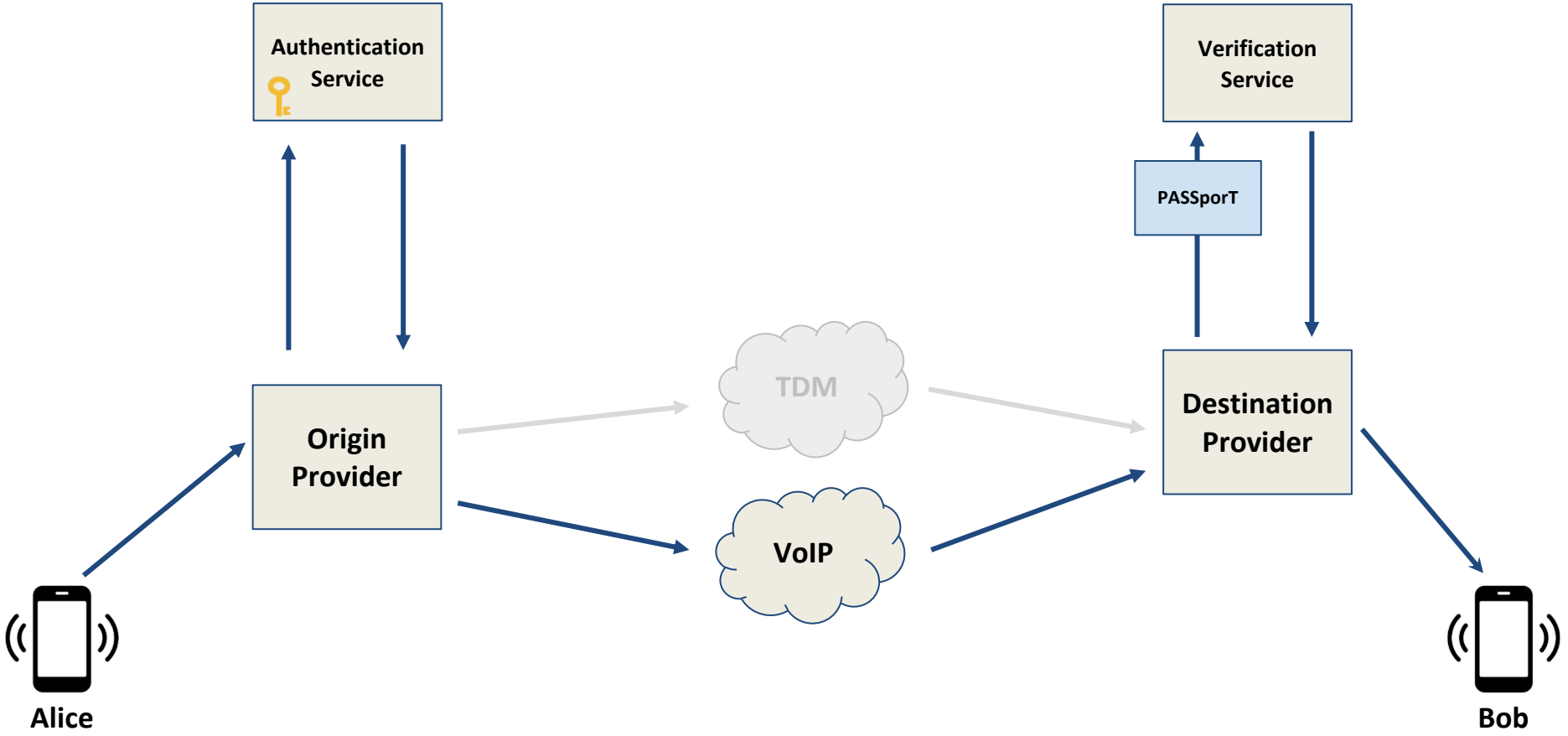

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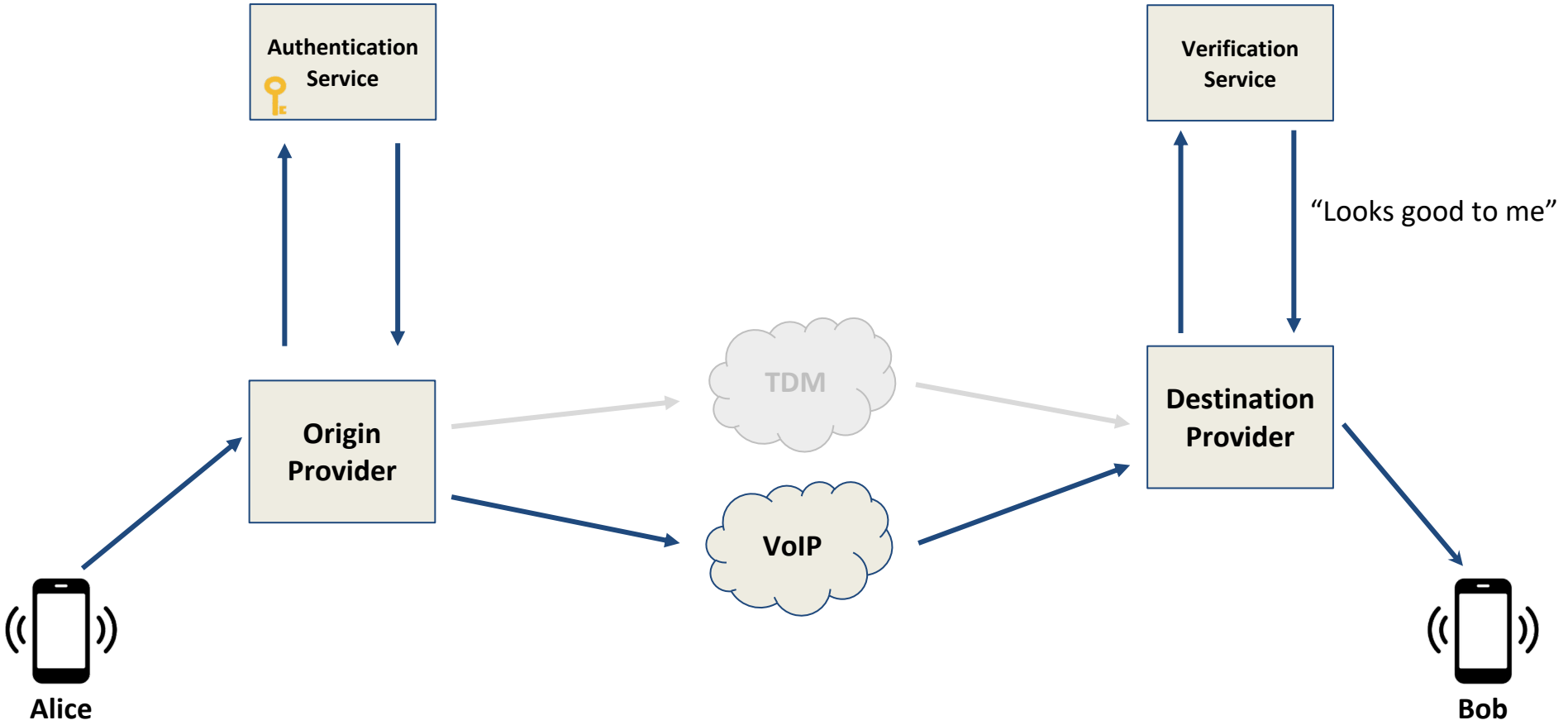

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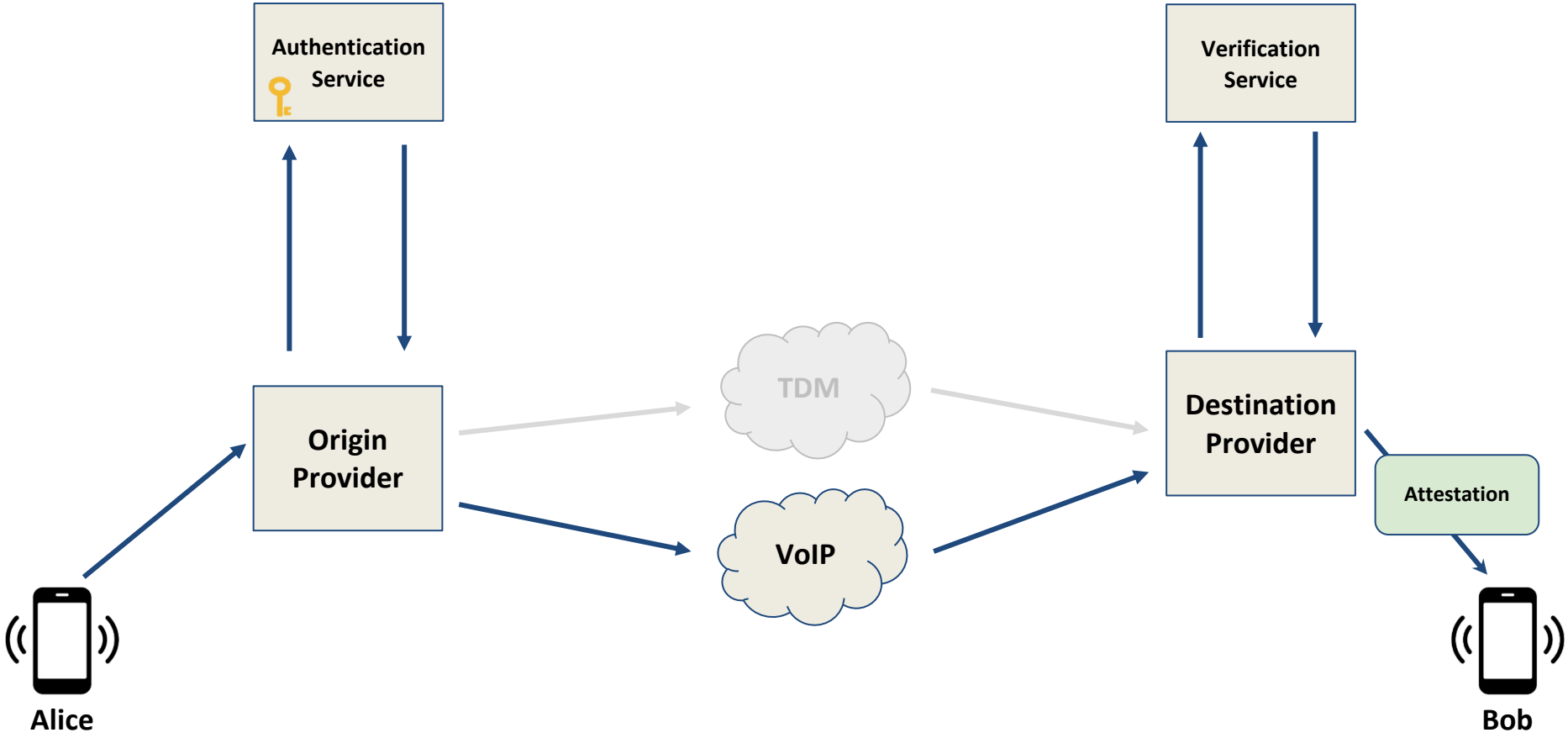

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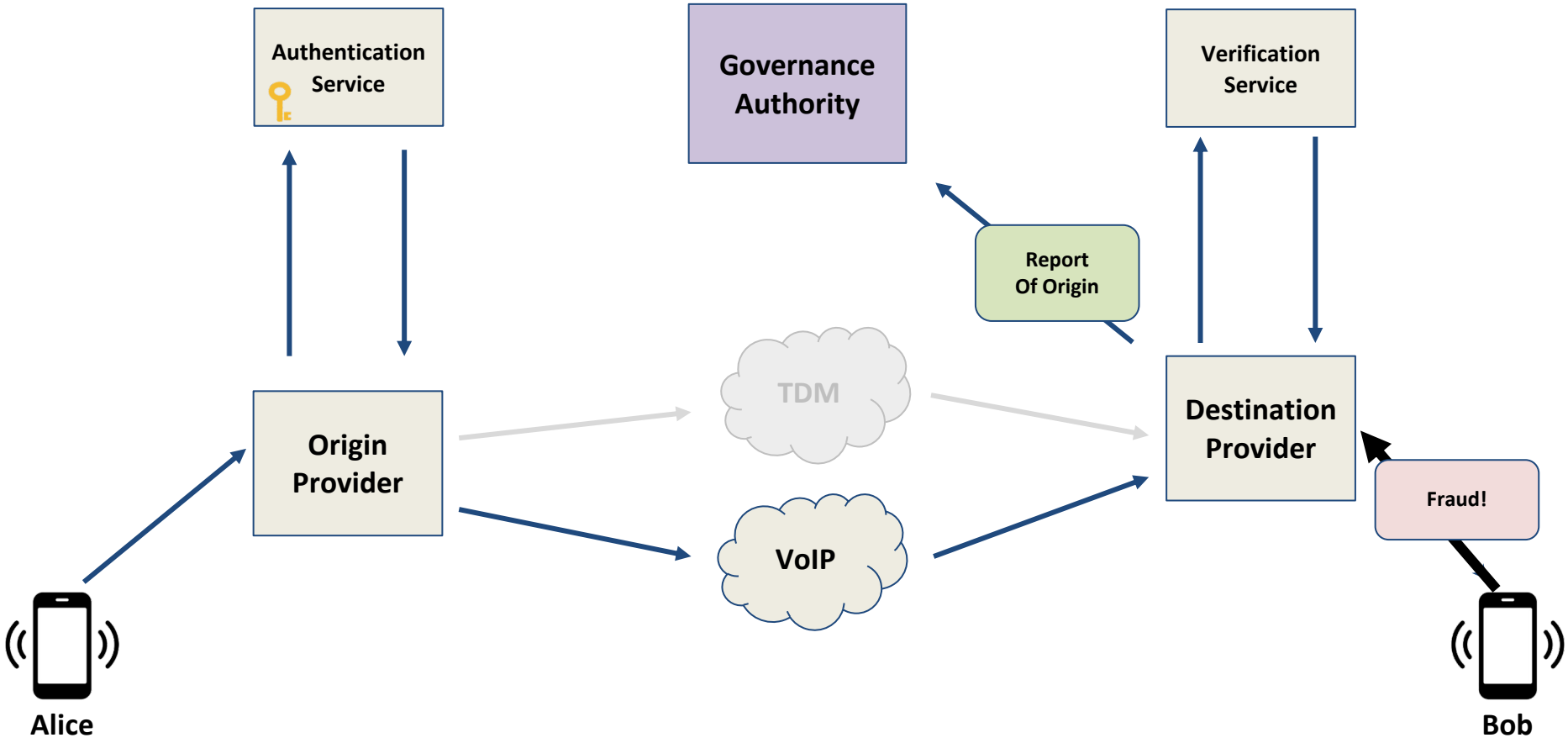

SIP INVITE With STIR/SHAKEN

```
INVITE sip:+14155552222@example.att.com SIP/2.0
Via: SIP/2.0/UDP 1.2.3.4:5060;branch=z9hG4bK776asdhds
Max-Forwards: 70
To: "Bob" <sip:+14155552222@example.att.com>
From: "Alice" <sip:+14155551111@example.pstn.verizon.com>;tag=1
Call-ID: a84b4c76e66710
CSeq: 1 INVITE
Contact: "Alice" <sip:+14155551111@1.2.3.4:5060>
Content-Length:
Identity:
eyJhbGciOiJFUzI1NiIsInBwdCI6InNoYWtlbiIsInR5cCI6InBhc3Nwb3J0IiwieDV1IjoiaHR0cH
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EScb9otFNDxOCTjerg;info=<https://cert.example.org/passport.pem>;ppt="shaken"
```

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Via: SIP/2.0/UDP 1.2.3.4:5060;branch=z9hG4bK776asdhds
Max-Forward
To: "Bob" <
From: "Alic
Call-ID: a8
CSeq: 1 INV
Contact: "A
Content-Len
Identity:
eyJhbGciOiJFUzI1NiIsInBwdCI6InNoYWtlbiIsInR5cCI6InBhc3Nwb3J0IiwieDV1IjoiaHR0cH
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1ThRJ74MktxeLGaZQGAir8pcIvmB6OQEMgS4Ym7FPwGxm3tDUTRTpQ5X0relYset-
EScb9otFNDxOCTjerg;info=<https://cert.example.org/passport.pem>;ppt="shaken"
```

```
{
  "alg": "ES256",
  "ppt": "shaken",
  "typ": "passport",
  "x5u": "https://cert.example.org/passport.pem"
}
```

(ECDSA using P-256 and SHA-256)

SIP INVI

```
{
  "attest": "A",
  "dest": {
        "tn": [
        "14155552222"
        ]
  },
  "iat": 1471375418,
  "orig": {
        "tn": "14155551111"
  },
  "origid": "123e4567-e89b-12d3-a456-426655440000"
}
```

```
INVITE sip:+1
Via: SIP/2.0/
Max-Forwards:
To: "Bob" <si
From: "Alice"
Call-ID: a84b
CSeq: 1 INVIT
Contact: "Ali
Content-Lengt
Identity:
eyJhbGciOiJFUzI1NiIsInBwdCI6InNoYWtlbiIsInR5cCI6InBhc3Nwb3J0IiwieDV1IjoiaHR0cH
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eyJhbGciOiJFUzI1NiIsInBwdCI6InNoYWtlbiIsInR5cCI6InBhc3Nwb3J0IiwieDV1IjoiaHR0cH
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TEyMTIifSwib3JpZ2lkIjoiMTIzZTQ1NjctZTg5Yi0xMmQzLWE0NTYtNDI2NjU1NDQwMDAwIn0._V4
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M6Ly9jZXJ0LmV4YW1wbGUub3JnL3Bhc3Nwb3J0LnBlbSJ9.eyJhdHRlc3QiOiJBIiwiZGVzdCI6eyJ
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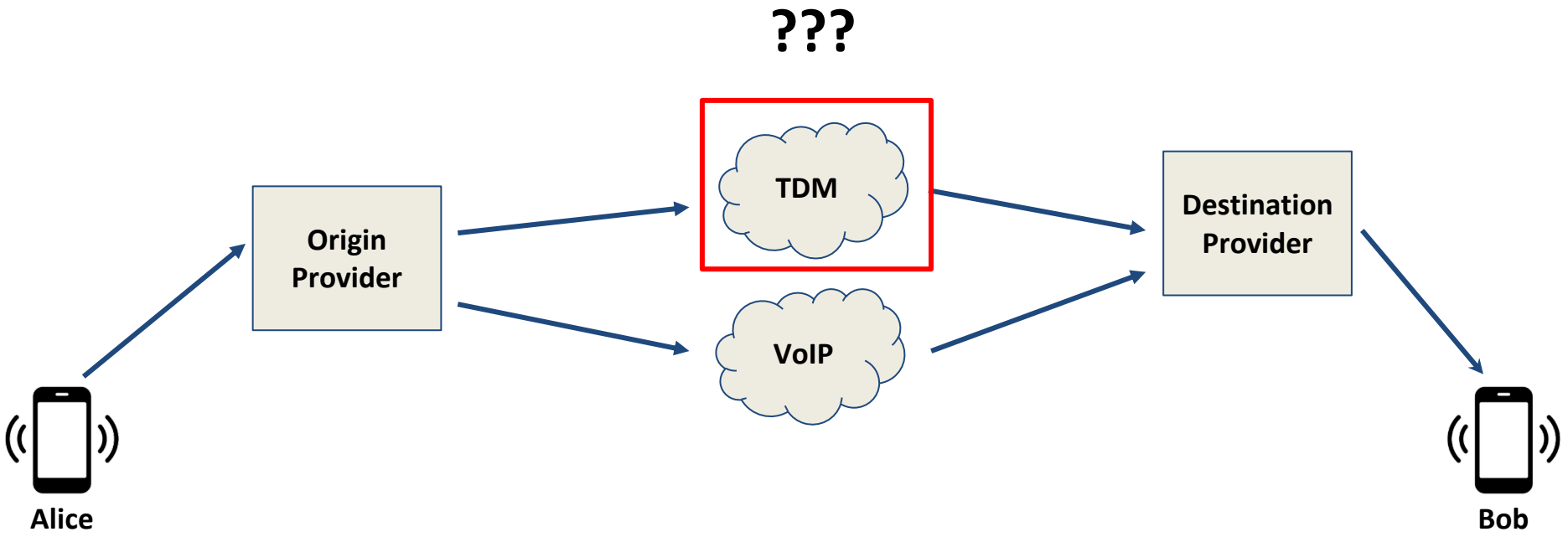
To: "Bob" <sip:+14155552222@example.att.com>
From: "Alice" <sip:+14155551111@example.pstn.verizon.com>;tag=1
Call-ID: a84b4c76e66710
CSeq: 1 INVITE
Contact:
Content-Length: 0
Identity:
eyJhbGciOiJFUzI1NiIsInBwdCI6InNoYWtlbiIsInR5cCI6InBhc3Nwb3J0IiwieDV1IjoiaHR0cH
M6Ly9jZXJ0LmV4YW1wbGUub3JnL3Bhc3Nwb3J0LnBlbSJ9.eyJhdHRlc3QiOiJBIiwiZGVzdCI6eyJ
0biI6WyIxMjEyNTU1MTIxMyJdfSwiaWF0IjoxNDcxMzc1NDE4LCJvcmlnIjp7InRuIjoiMTIxNTU1N
TEyMTIifSwib3JpZ2lkIjoiMTIzZTQ1NjctZTg5Yi0xMmQzLWE0NTYtNDI2NjU1NDQwMDAwIn0. V4
1ThRJ74MktxeLGaZQGAir8pcIvmB6OQEMgS4Ym7FPwGxm3tDUTRTpQ5X0relYset-
EScb9otFNDxOCTjerg;info=<https://cert.example.org/passport.pem>;ppt="shaken"
```

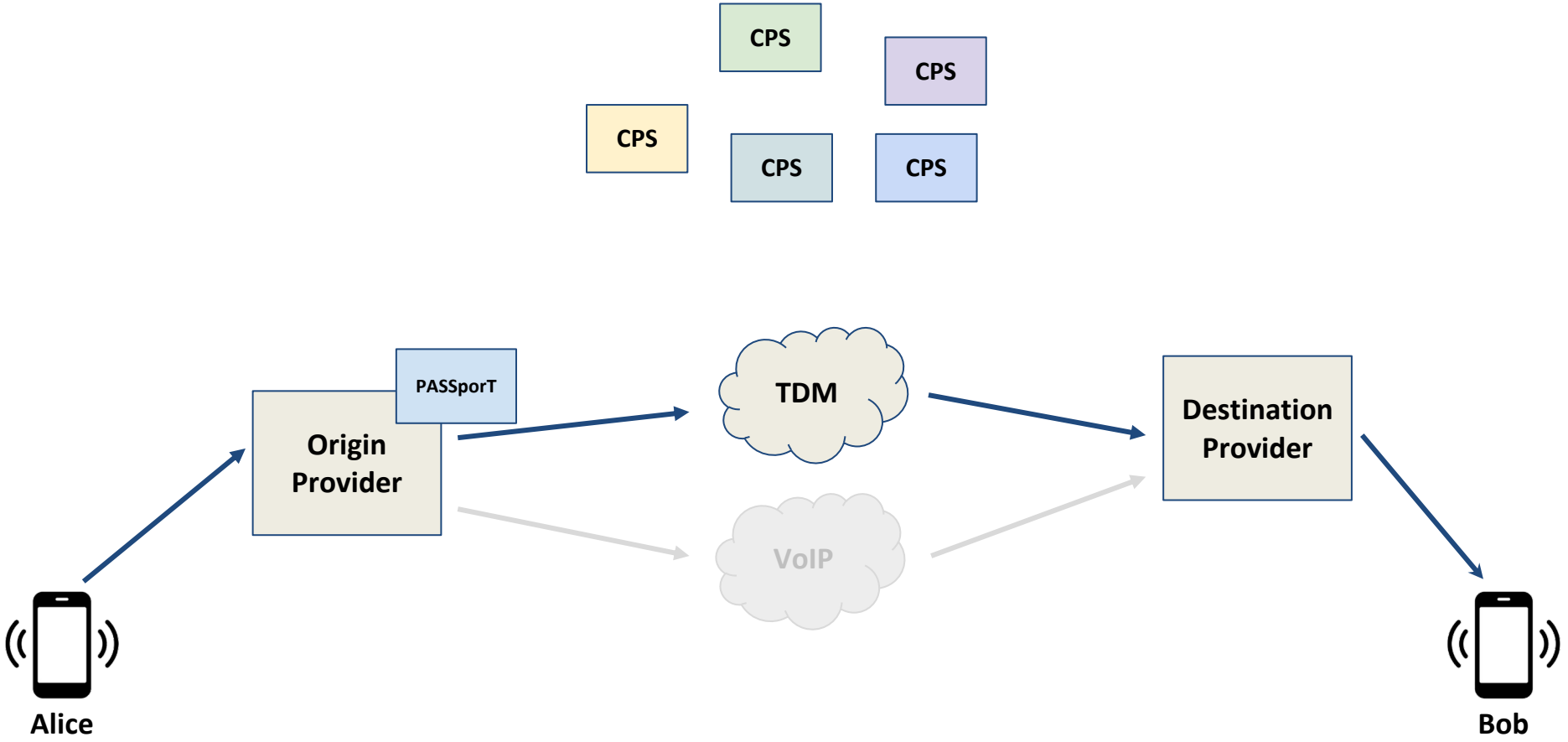
ECDSASHA256(base64(header) + "." + base64(payload), SK)

Note: This signature is for illustrative purposes and doesn't actually verify properly

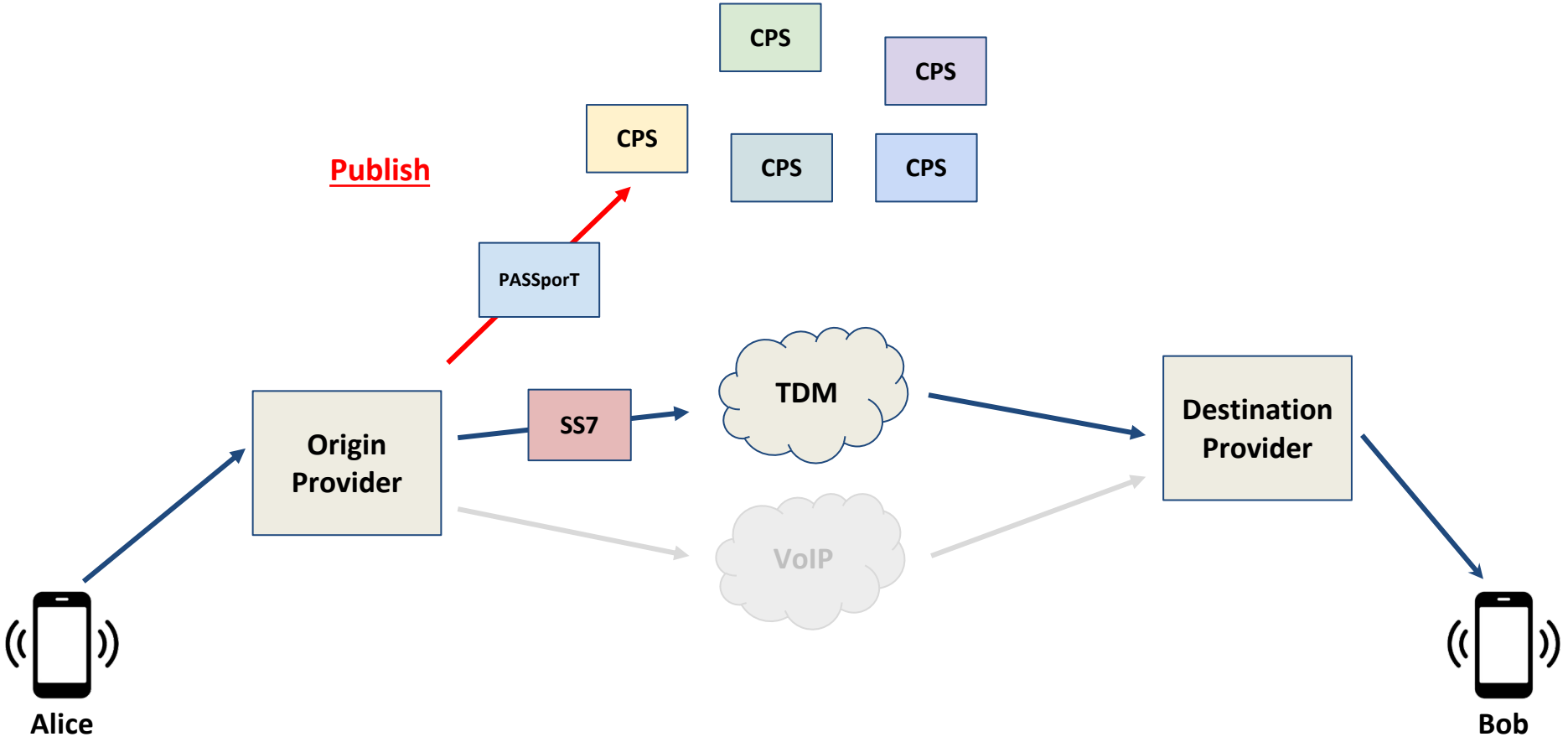
STIR/SHAKEN for TDM (?)



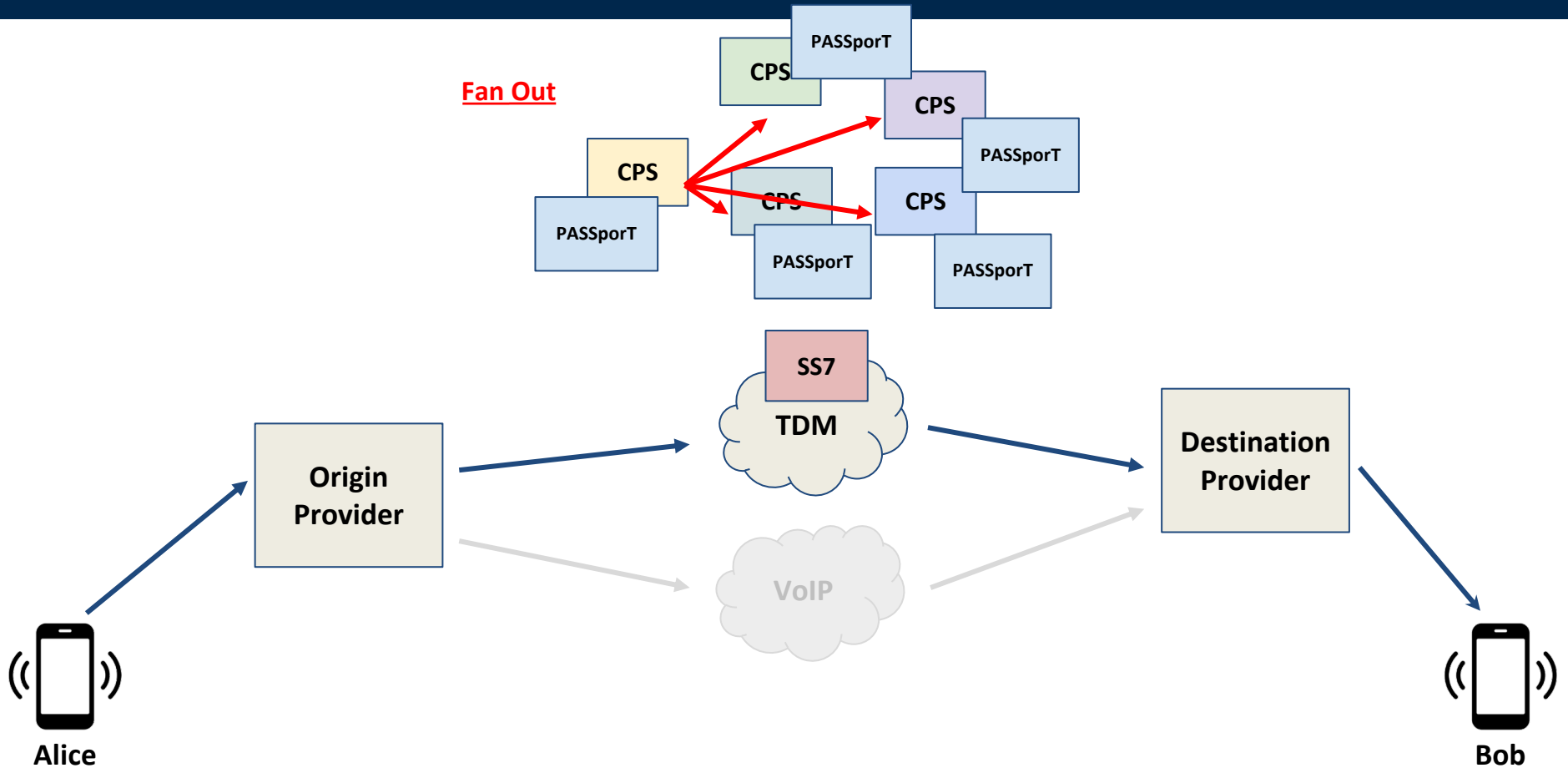
Out-Of-Band STIR/SHAKEN: Architecture



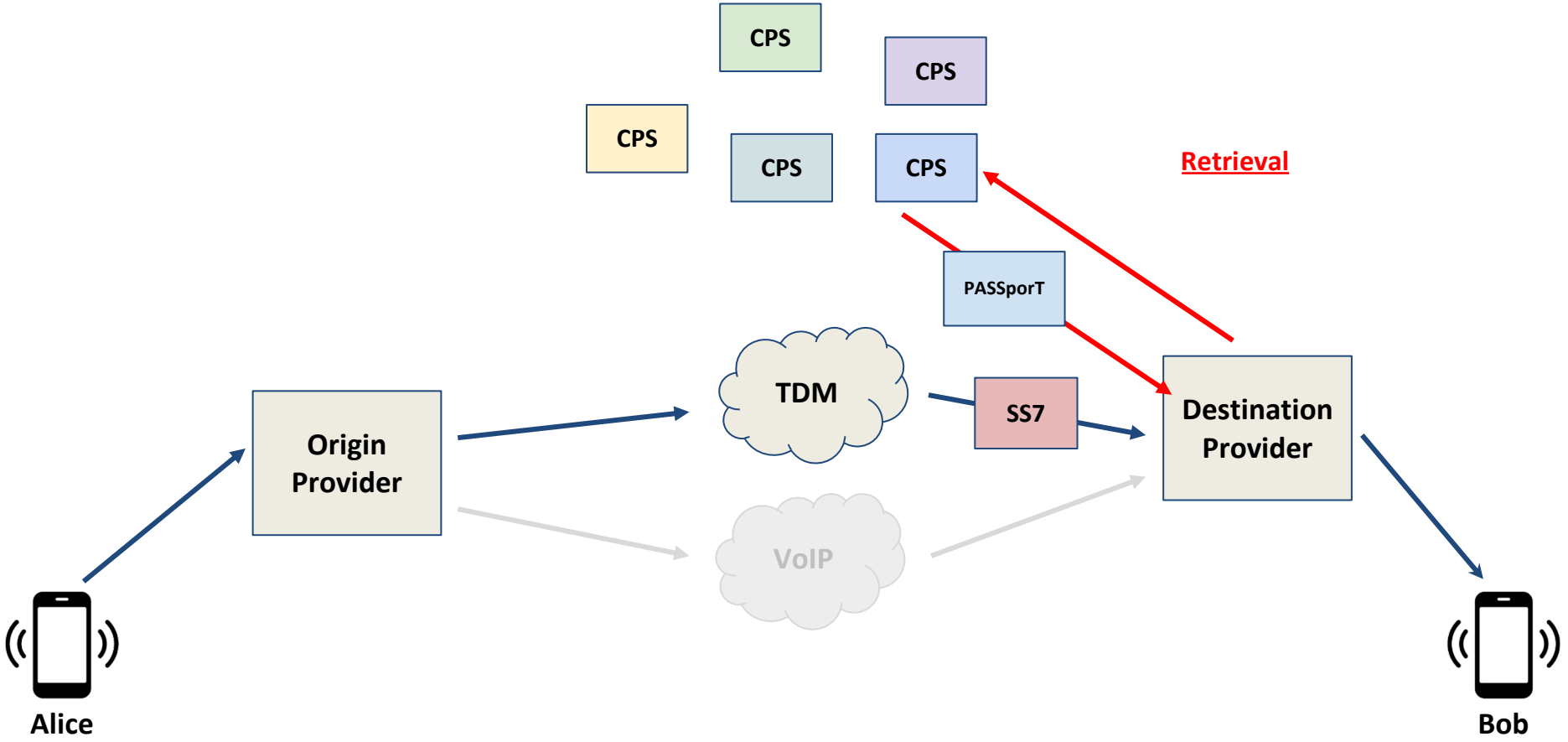
Out-Of-Band STIR/SHAKEN: Architecture



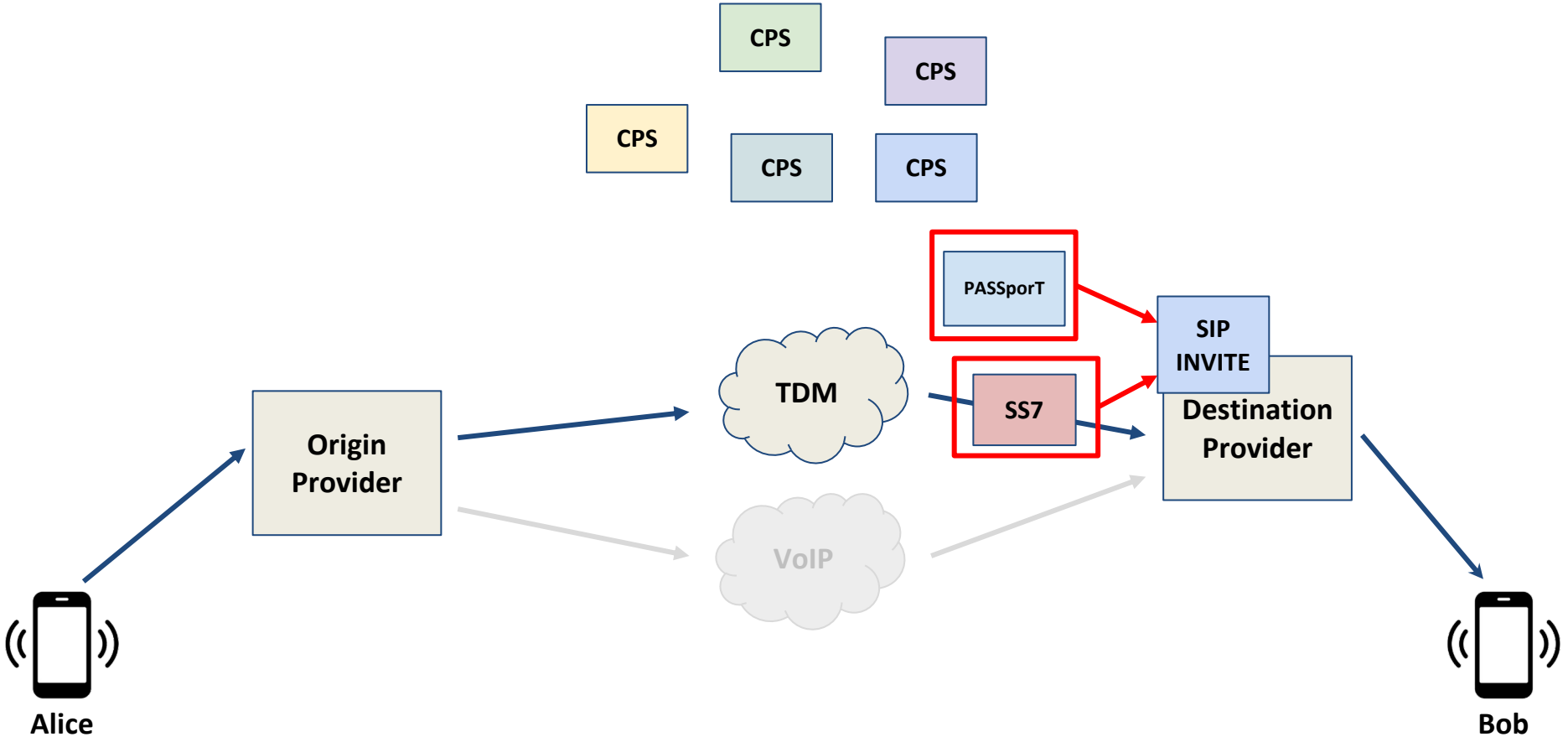
Out-Of-Band STIR/SHAKEN: Architecture



Out-Of-Band STIR/SHAKEN: Architecture



Out-Of-Band STIR/SHAKEN: Architecture



Summary of Background

- PSTN: either just VoIP or VoIP + TDM
- SIP: setup/teardown protocol for VoIP calls. Has “INVITE” msg
- STIR/SHAKEN lets telcos make assertions about caller identity
- PASSporTs: Signed metadata (to/from numbers) in SIP INVITE
- For TDM calls, PASSporTs held by “drop box” (CPS)

Flaws

Deniability of Call Metadata

This PASSporT is cryptographic proof that Alice called Bob!

```
INVITE sip:+14155552222@example.att.com SIP/2.0
Via: SIP/2.0/UDP 1.2.3.4:5060;branch=z9hG4bK776asdhds
Max-Forwards: 70
To: "Bob" <sip:+14155552222@example.att.com>
From: "Alice" <sip:+14155551111@example.pstn.verizon.com>;tag=1
Call-ID: a84b4c76e66710
CSeq: 1 INVITE
Contact: "Alice" <sip:+14155551111@1.2.3.4:5060>
Content-Length:
Identity:
eyJhbGciOiJFUzI1NiIsInBwdCI6InNoYWtlbiIsInR5cCI6InBhc3Nwb3J0IiwieDV1IjoiaHR0cH
M6Ly9jZXJ0LmV4YW1wbGUub3JnL3Bhc3Nwb3J0LnBlbSJ9.eyJhdHRlc3QiOiJBIiwiZGVzdCI6eyJ
0biI6WyIxMjEyNTU1MTIxMyJdfSwiaWF0IjoxNDcxMzc1NDE4LCJvcmlnIjp7InRuIjoiMTIxNTU1N
TEyMTIifSwib3JpZ2lkIjoiMTIzZTQ1NjctZTg5Yi0xMmQzLWE0NTYtNDI2NjU1NDQwMDAwIn0._V4
1ThRJ74MktxeLGaZQGAir8pcIvmB6OQEMgS4Ym7FPwGxm3tDUTRTpQ5X0relYset-
EScb9otFNDxOCTjerg;info=<https://cert.example.org/passport.pem>;ppt="shaken"
```

Why is deniability important for call metadata?

- Makes stolen call logs easier to verify => incentivizes theft.
- Reduces “ephemerality” of calls.

ET Telecom.com
From The Economic Times

Get App

Nepal Telecom call details stolen by Chinese hackers

These hackers broke into 10 telecoms companies to steal customers' phone records

Hewlett-Packard spying scandal

Article Talk

From Wikipedia, the free encyclopedia

involved investigators impersonating HP board members and nine journalists (including reporters for CNET, the *New York Times* and the *Wall Street Journal*) in order to obtain their phone records. The

The Washington Post
Democracy Dies in Darkness

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Leaked files from Chinese firm show vast international hacking effort

By Christian Shepherd, Cate Cadell, Ellen Nakashima, Joseph Menn and Aaron Schaffer

Updated February 22, 2024 at 10:01 a.m. EST | Published February 21, 2024 at 8:00 p.m. EST

to have successfully breached. The haul included 95.2 gigabytes of immigration data from India and a 3 terabyte collection of call logs from South Korea’s LG U Plus telecom provider. The group also targeted other telecommunications firms in Hong Kong, Kazakhstan, Malaysia, Mongolia, Nepal and Taiwan. The Indian Embassy in Washington did

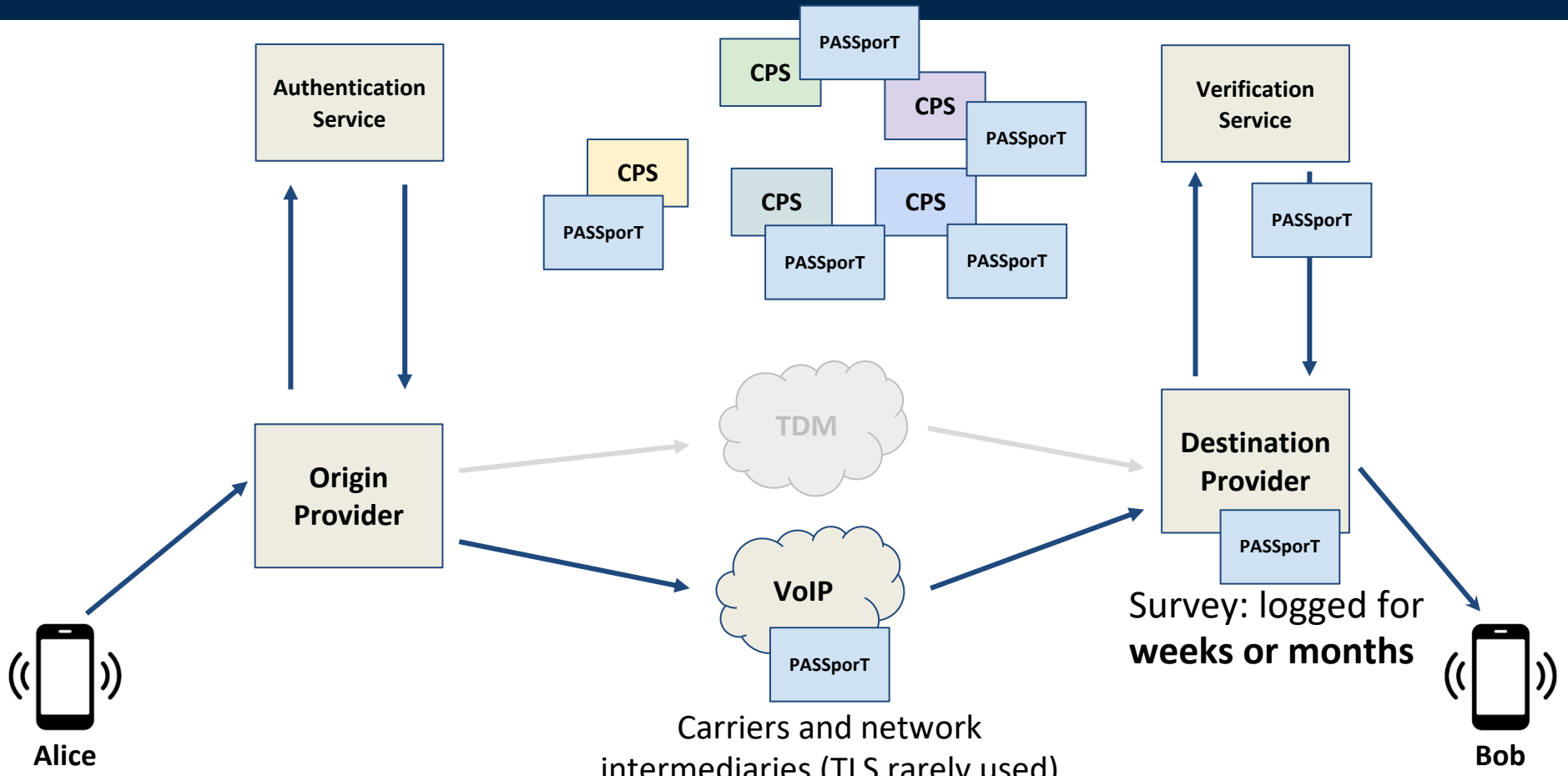
Comparison to DKIM for Email

- DKIM, STIR/SHAKEN goals similar
- DKIM signatures are used to authenticate leaks
- DKIM signs email body, STIR/SHAKEN only metadata
- However, PASSporTs more available to intermediaries…

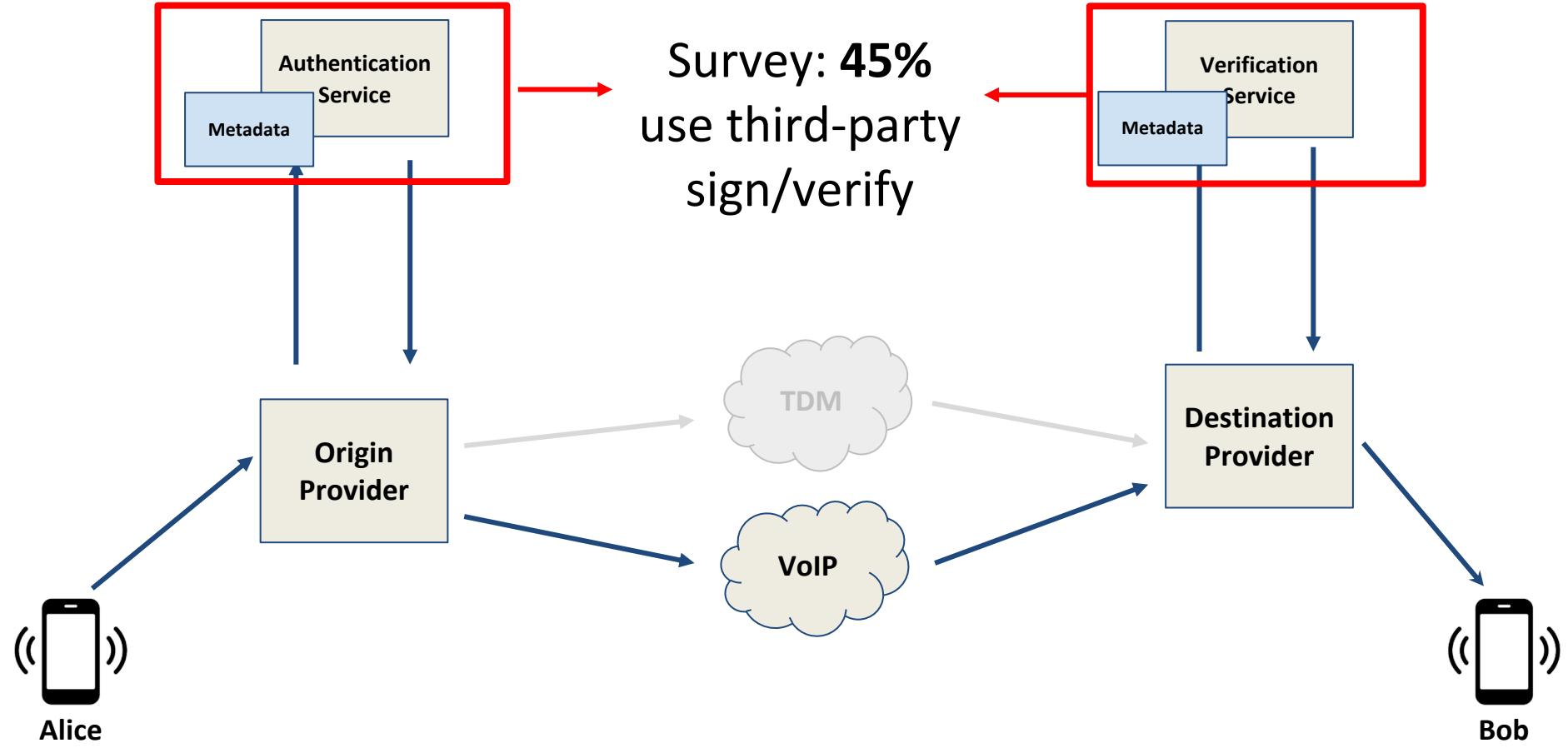
Authenticating Email Using DKIM and ARC, or How We Analyzed the Kasowitz Emails

The AP worked to authenticate the 200-odd documents, in some cases by verifying the digital signatures carried in email headers.

PASSporTs are everywhere…



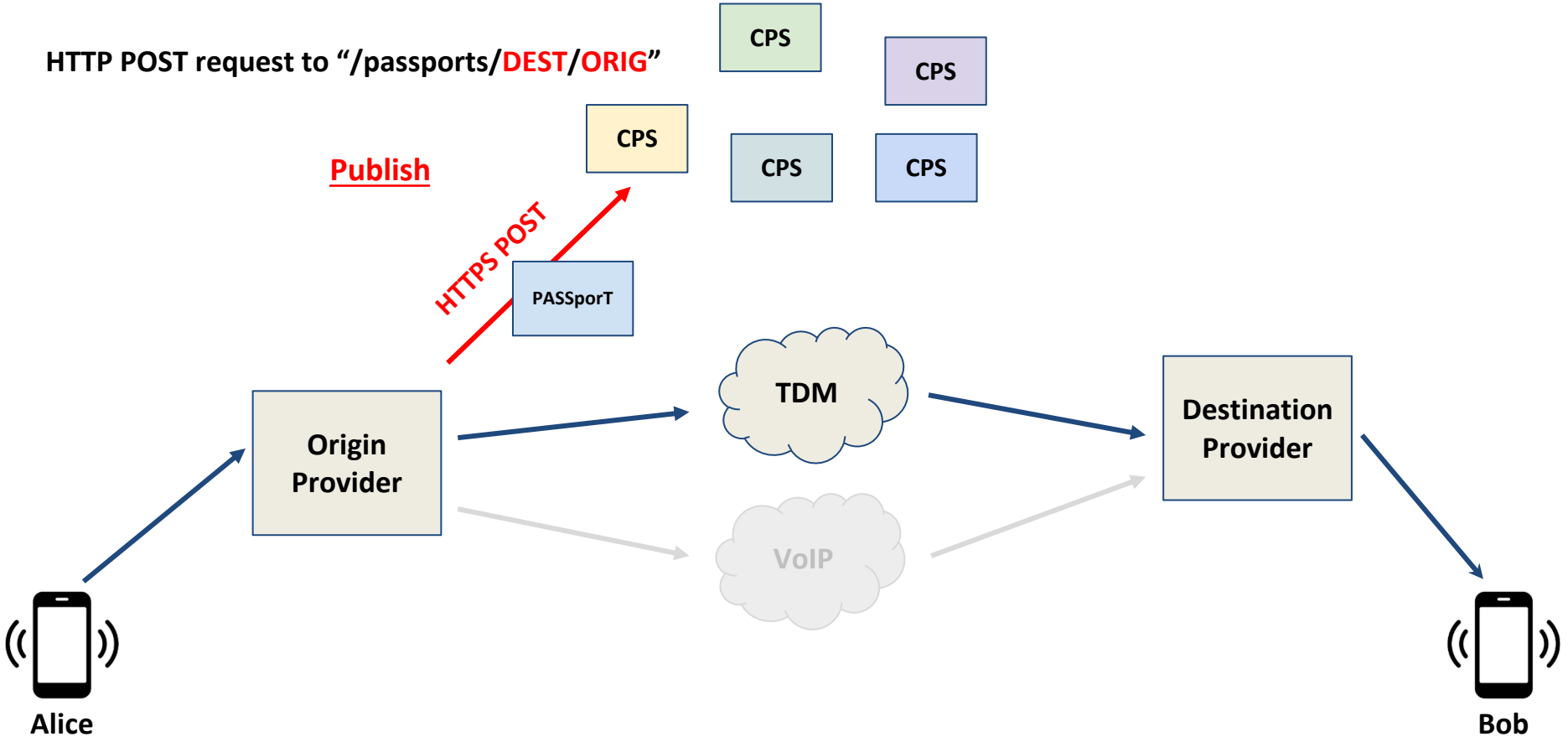
Metadata Leakage



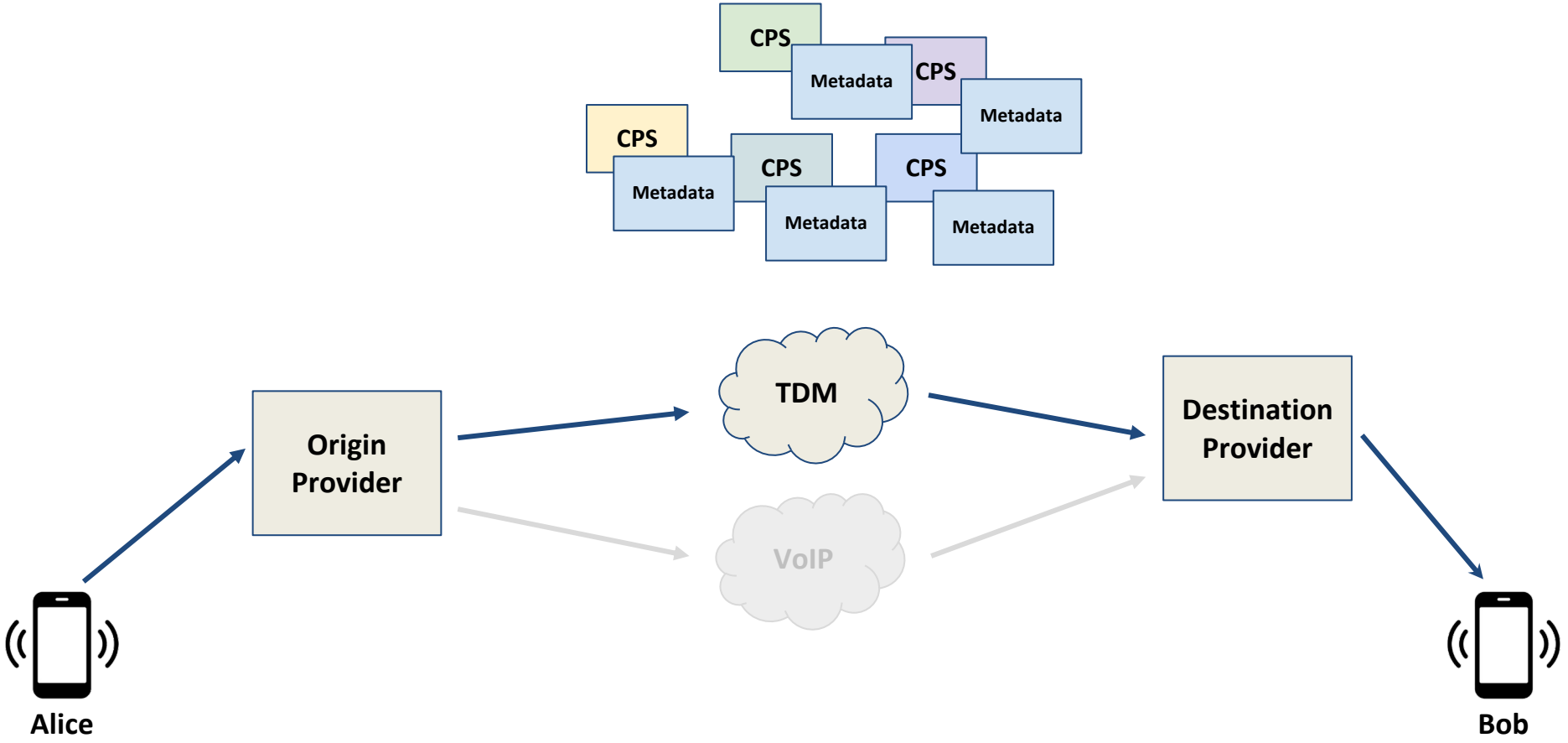
Why is call metadata sensitive?

Abortion clinic, political party, suicide hotline, religious organization, journalist, rehab…

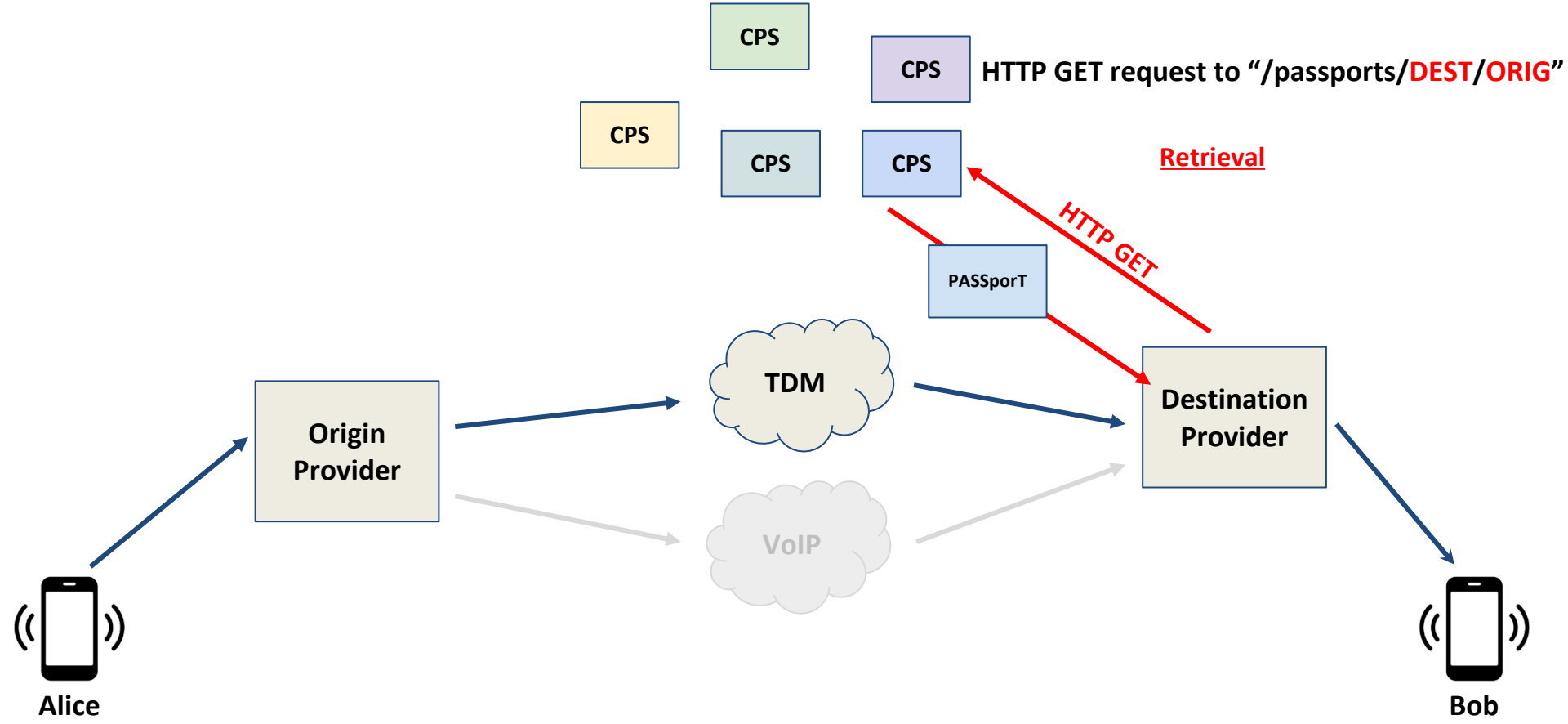
Out-Of-Band *requires* Metadata Leakage



Out-Of-Band *requires* Metadata Leakage



Out-Of-Band *requires* Metadata Leakage



PKI Issues

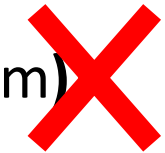
- No certificate transparency
- Certificate misissuance
- Revocation issues
- Policy administrator is single point of failure for entire PKI

Solutions

Security + Privacy Goals

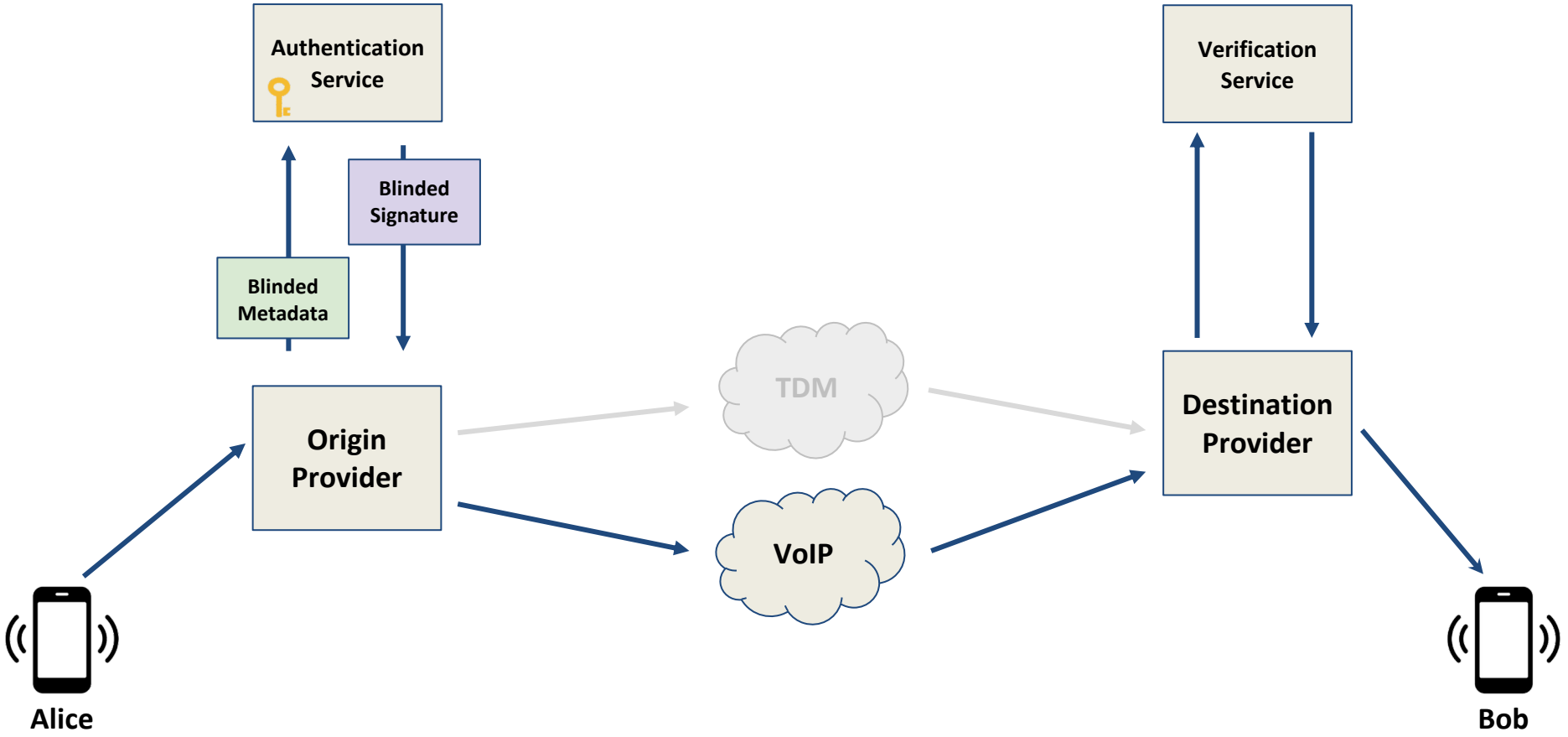
- **Metadata Hiding:** Authentication and verification service can't see PASSporT metadata
- **Unlinkability:** Authentication and verification service cannot correlate phone number or provider pairs
- **Deniability:** Origin callers can deny placing a call
- **Reportability:** Ability to report to governance authority
- **Confidentiality:** On-path parties can't see PASSporT contents

Sign(Hash(metadata || random**)**

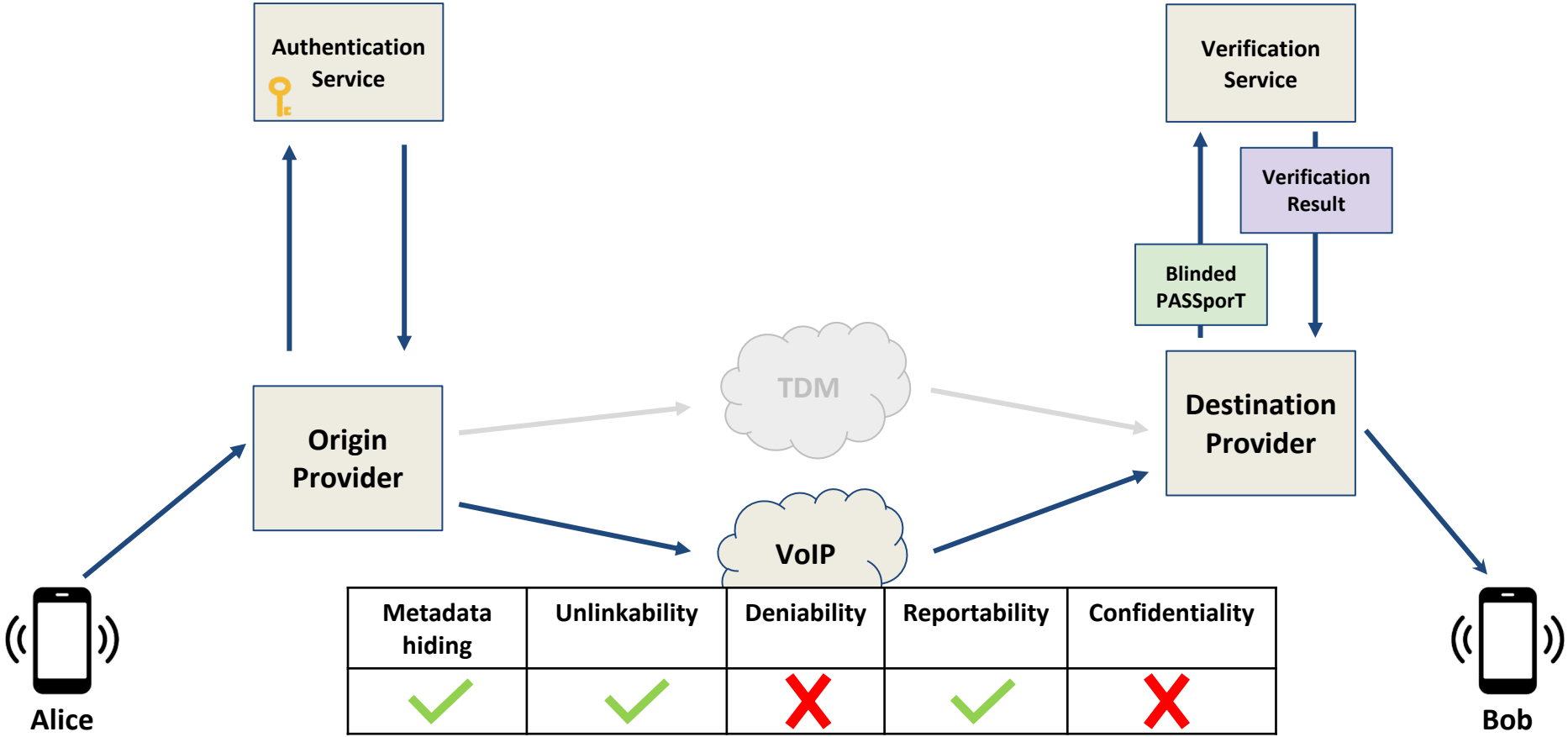


Third parties can correlate sign + verify, learn partial information about (to, from) pair

Blind Signing (e.g., RFC 9474)

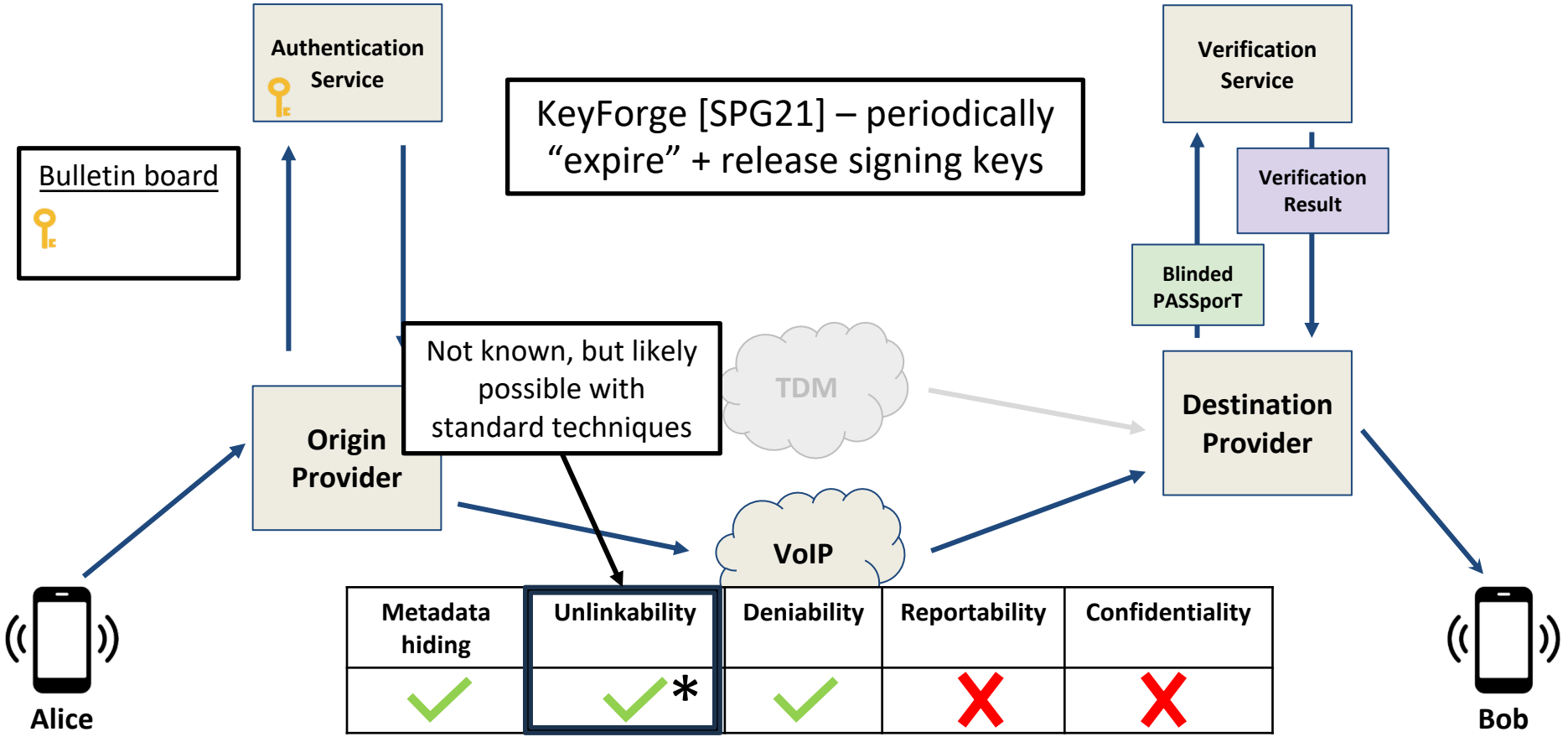


Blind (or in-house) Verification

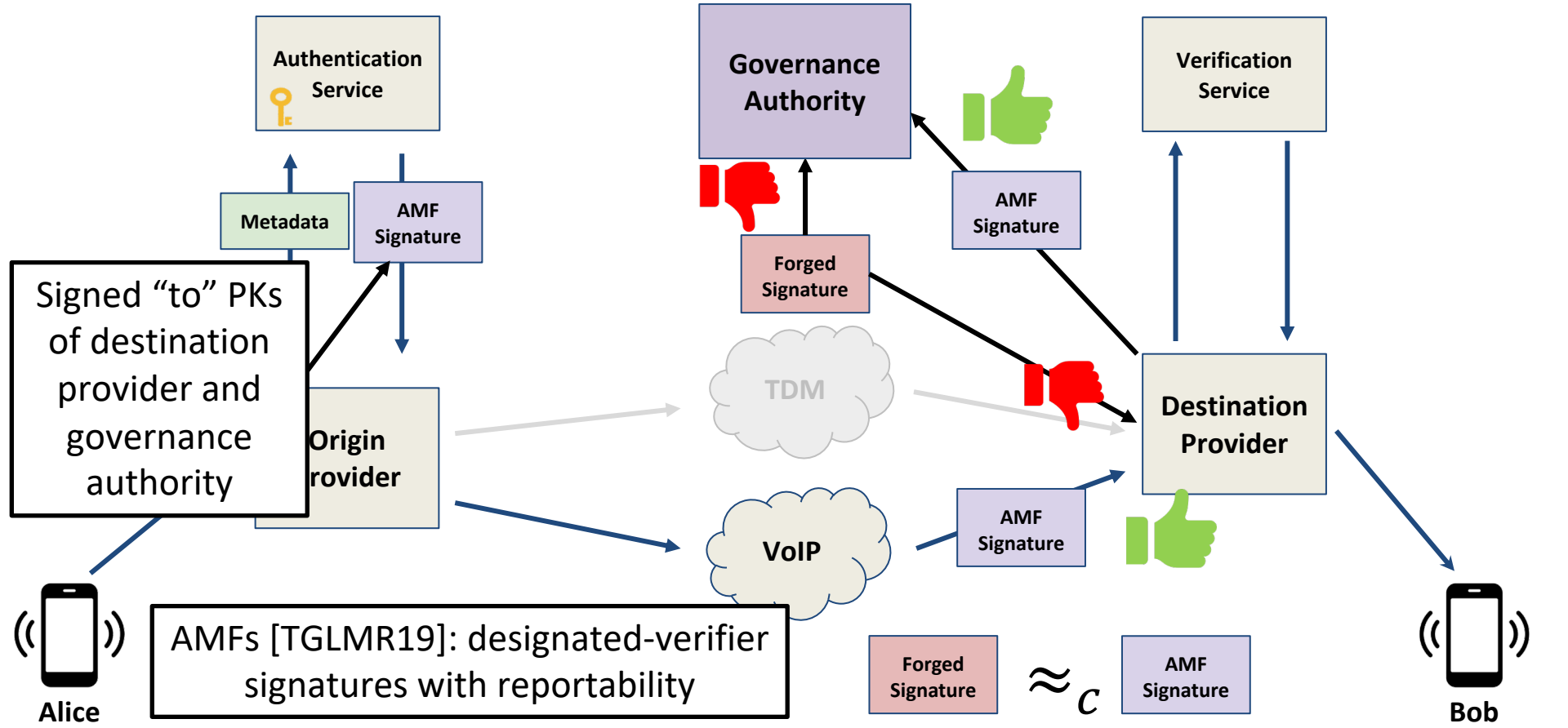


Metadata hiding	Unlinkability	Deniability	Reportability	Confidentiality
✓	✓	✗	✓	✗

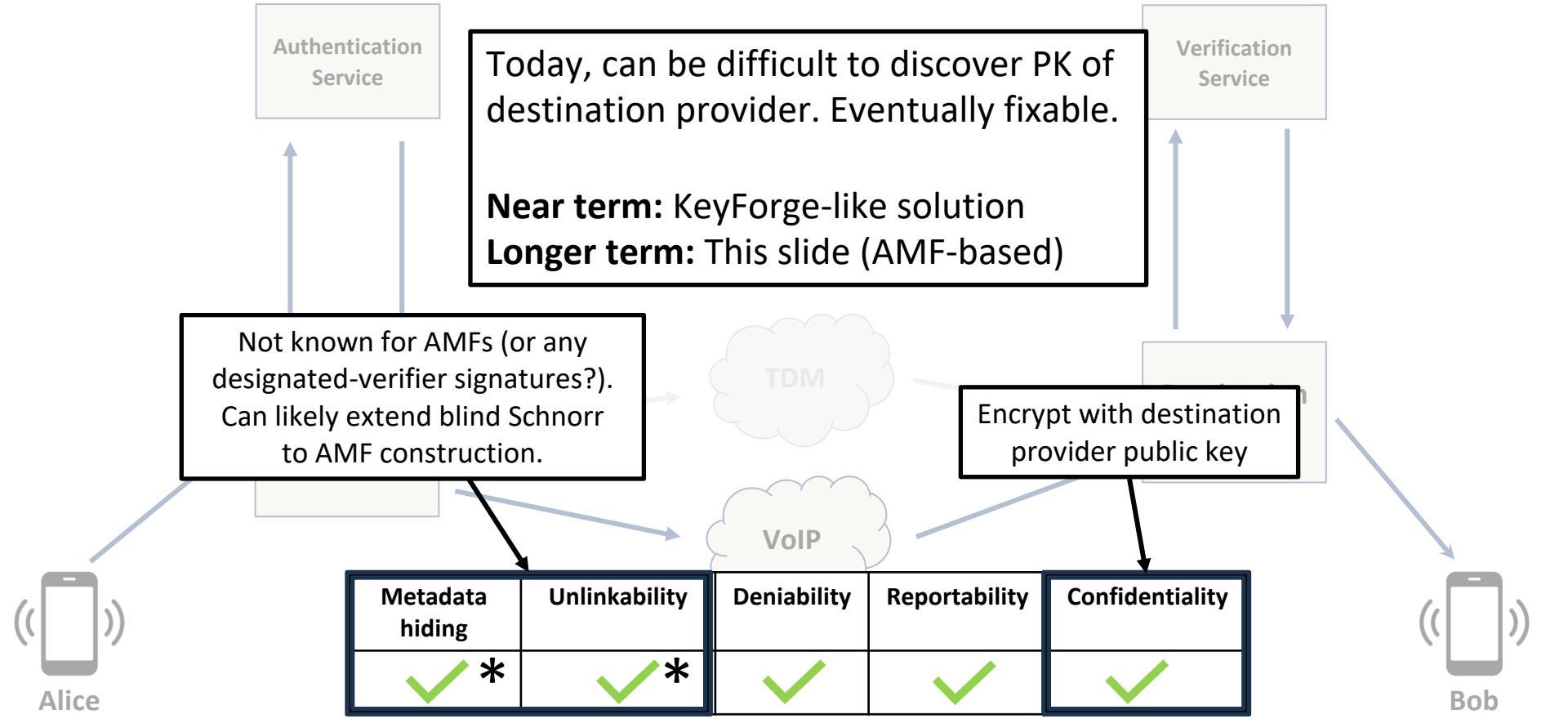
Achieving deniability?



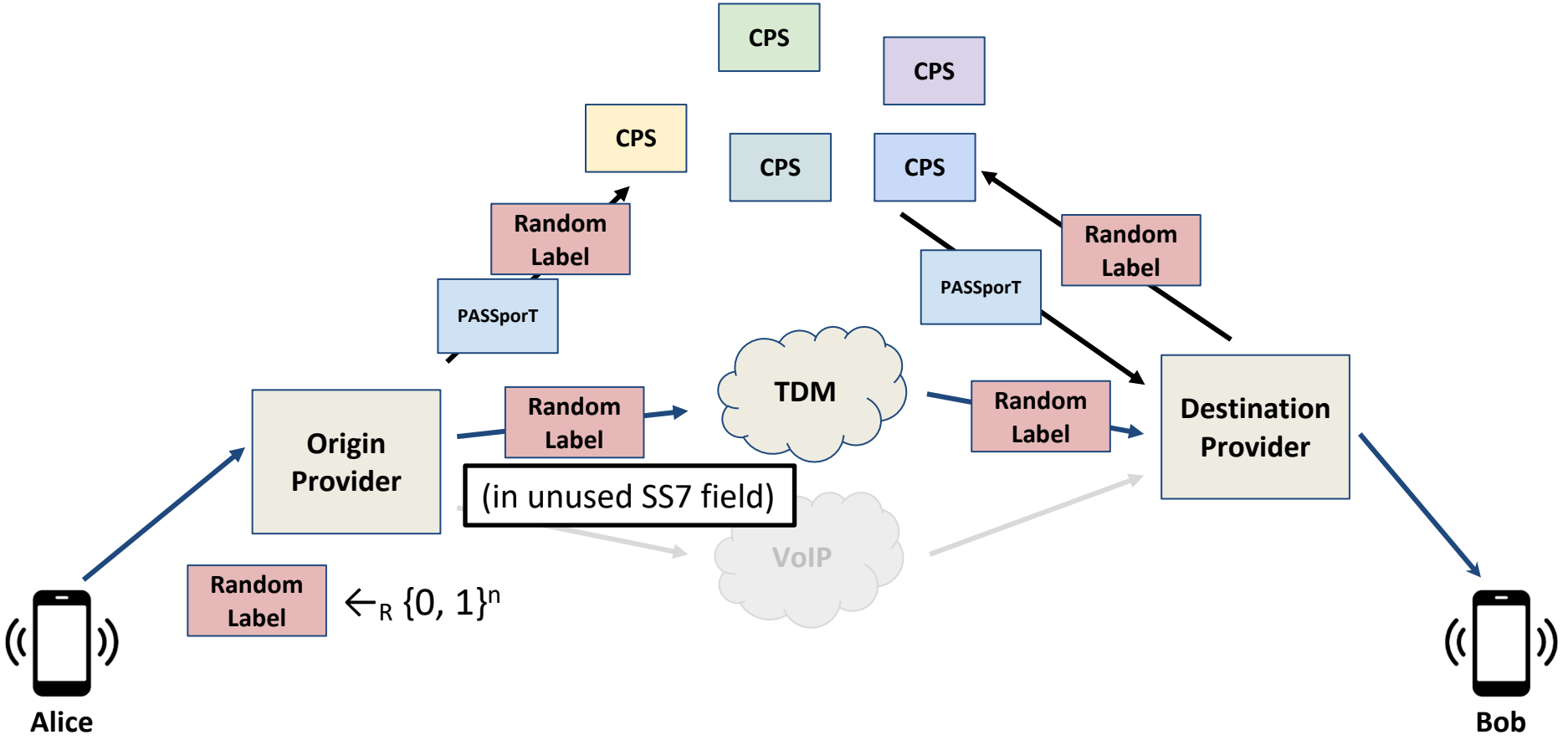
Asymmetric Message Franking (AMFs)



AMFs, blind signing, and encrypted PASSporTs



Improving the Out-of-Band Protocol



Conclusion

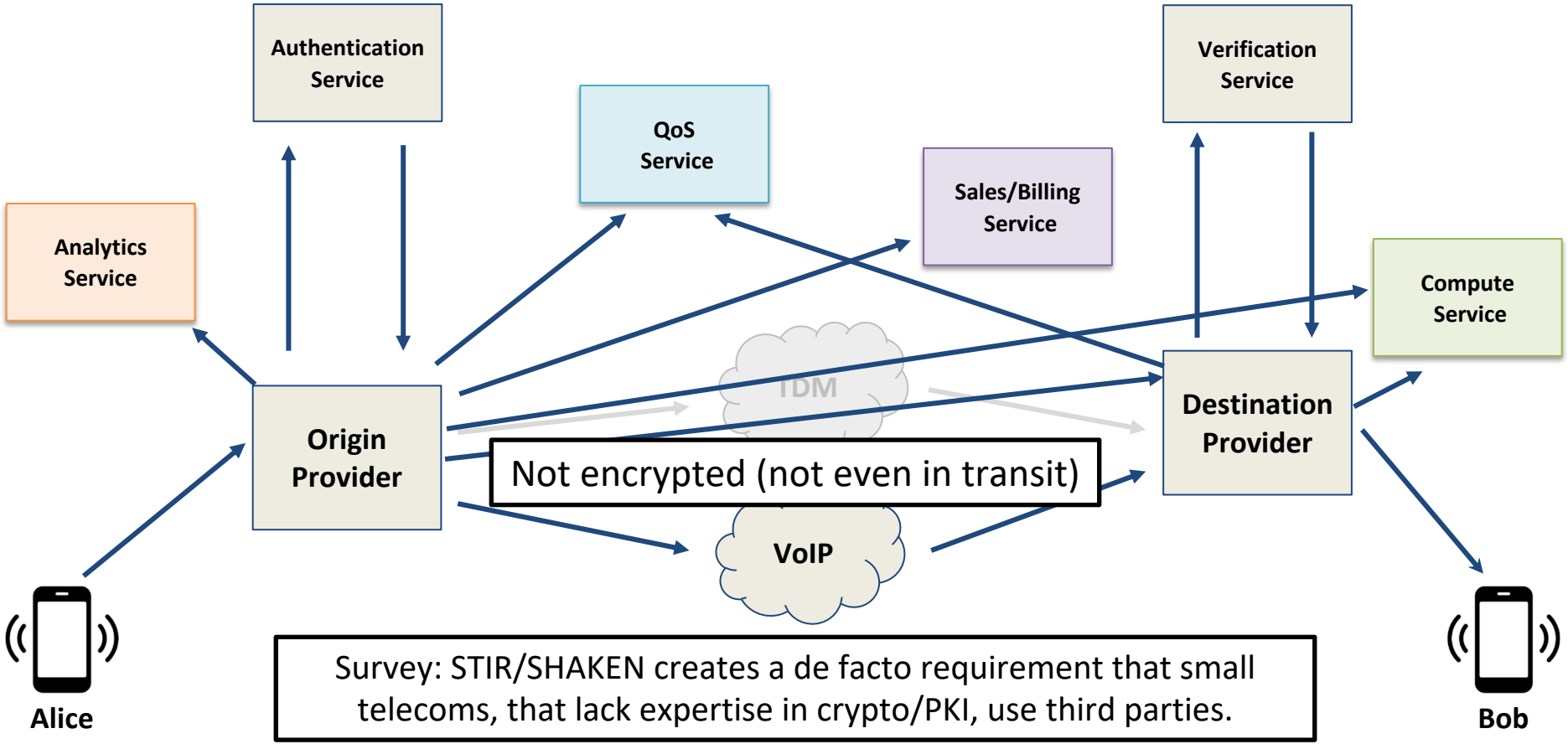
- STIR/SHAKEN is a new protocol in use by ~all telecoms operating in the U.S.
- The STIR/SHAKEN ecosystem has a variety of privacy and security flaws
  - Non-repudiable metadata
  - New metadata leakage
  - Numerous PKI issues
- We are in the process of designing solutions to these issues
  - Blind signing verification
  - Deniable signatures
  - Improved out-of-band protocol

Thanks to:
Matt Hardeman & Ryan Hurst – Martini Security
Yoon-Sung Ji – University of Michigan

Thanks for listening! Any questions?

Questions

Why criticize STIR/SHAKEN?



Survey: STIR/SHAKEN creates a de facto requirement that small telecoms, that lack expertise in crypto/PKI, use third parties.