# Network Security

## Anonymous Networks & Communications

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21 March 2016

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- More information: https://fyb.patternsinthevoid.net
  Including asciiart and My Little Ponies which bounce around in your browser (if you trust me enough to enable Javascript).
  It also has useful things: technical blogposts, project ideas and updates, my public keys and fingerprints, and, of course, links to all my code.

# Why should you care about privacy?

*"There is an entire genre of YouTube videos devoted to an experience which I'm certain that everyone in this room has had. It entails an individual, who, thinking they're alone, engages in some expressive behaviour – wild singing, girating dancing, some mild sexual activity – only to discover that, in fact, they are not alone, that there's a person watching and lurking, the discovery of which causes them to immediately cease what they're doing in horror. The sense of shame and humiliation in their face is palpable: it's the sense of 'this is something I'm willing to do only if no one else is watching.' This is the crux of the work on which I have been singularly focused for the sixteen months: the question of why privacy matters."*

*—Glenn Greenwald, TED Talk, October 2014*

# But I have nothing to hide...

*"Arguing that you don't care about the right to privacy because you have nothing to hide is no different than saying you don't care about free speech because you have nothing to say"*
*—Ed Snowden, Reddit AMA, 21 May 2015*

# Privacy is necessary for all other rights

## Even if you don't care about your own right to privacy . . .

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> *"Privacy is the right from which all others are derived. Privacy is the fountainhead of individuality. Without privacy, there is only the collective, there is only society, there is only influence from groups, from large powers, that shape every person to bring them into that fold and to make them all alike."*
>
> —*Ed Snowden, CIJ Logan Symposium, 12 March 2016*

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In the United States, it's not only unknowable *which* laws might apply: it's actually unknowable *how many* laws might apply at a given place and time – let alone how they may be interpreted by a particular court.

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*"Estimates of the current size and body of the [United States] federal criminal law vary. It has been reported that the Congressional Research Service cannot even count the current number of federal crimes. And these laws are scattered in over fifty titles of the United States Code, encompassing roughly 27,000 pages. Worse yet, the statutory code sections often incorporate, by reference, the provisions and sanctions of administrative regulations promulgated by various regulatory agencies. Estimates of how many such regulations exist are even less well settled, but the American Bar Association thinks there are nearly 10,000."*

*—James Duane, Regent Law Professor, in a lecture entitled "Don't Talk to Police", May 2012*

# Privacy is necessary for scientific progress

Privacy is essential for continued open progression of scientific understanding and human knowledge.

## From Juice Rap News, "Big Brother is WWWatching You":

*We're told we need safety; which is precious, yes,*
*But can a society that can enforce all it's laws ever progress?*
*Hindsight shows that many figures guilty of "thoughtcrime"*
*Turned out to be luminaries and heroes, before their time.*
*[images of Martin Luther King, Galileo, Huey P. Newton, others]*
*But if the surveillance state had reigned then, in this form and design,*
*Just think of all the progress we may've been denied:*
*Could lobbies for women's or gay rights have appeared and thrived?*
*Would revolutionary ideals have materialised?*
*Would science have pioneered or even survived,*

*If every word had been monitored by thought police and spies?*

https://youtu.be/o66FUc61MvU

# But most web traffic now is encrypted, right?

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# Actually, no, everything is not encrypted, not really

From the article:

> *"Early last year–before the Snowden revelations–encrypted traffic accounted for 2.29 percent of all peak hour traffic in North America, according to Sandvine's report. Now, it spans 3.8 percent. But that's a small jump compared to other parts of the world. In Europe, encrypted traffic went from 1.47 percent to 6.10 percent, and in Latin America, it increased from 1.8 percent to 10.37 percent."*
>
> *—Klint Finley on wired.com, May 16, 2014*

# . . . update from 2015

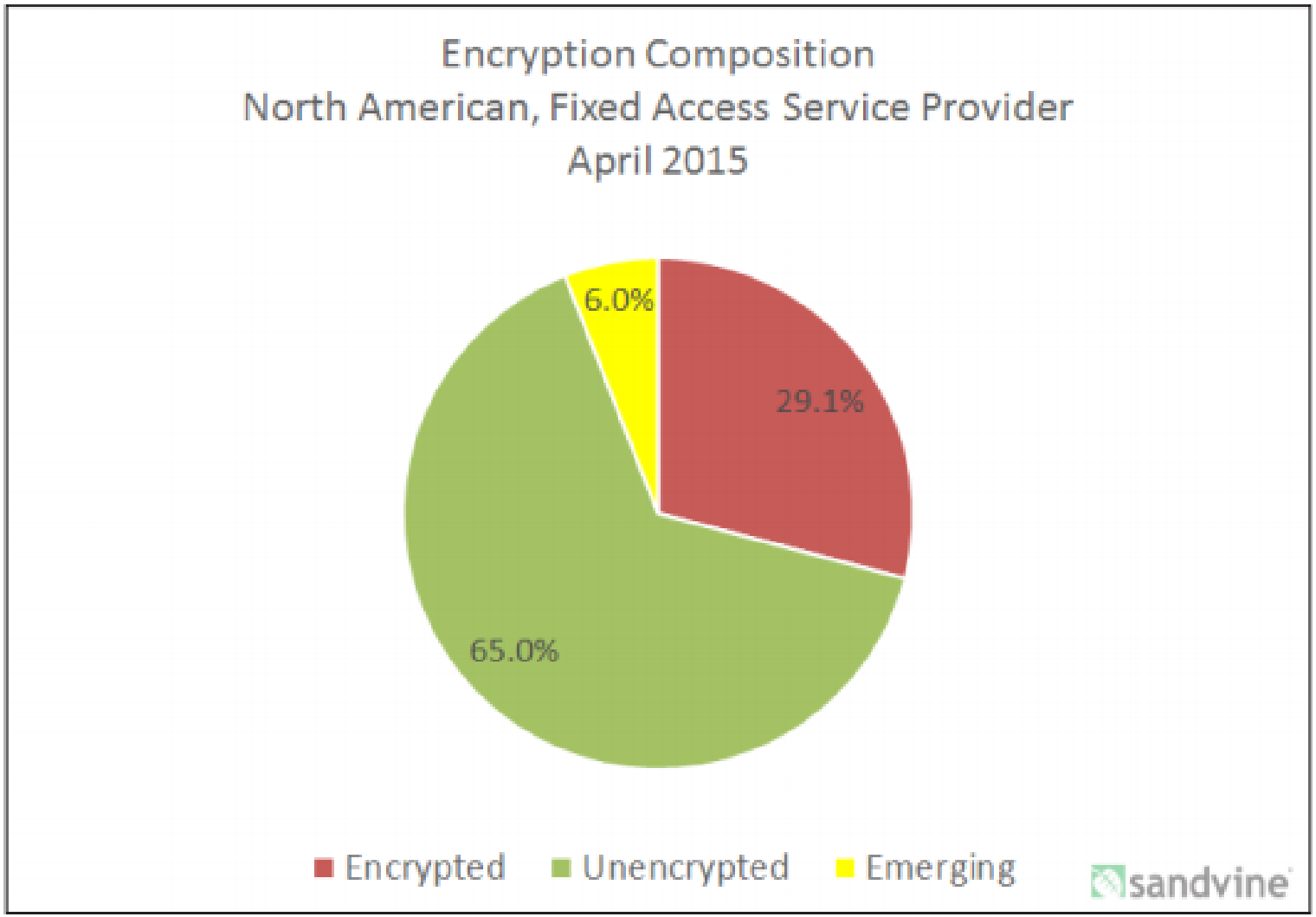


Figure 1 - Encryption Composition - North America, Fixed Access - April 2015

# . . . estimated for 2016

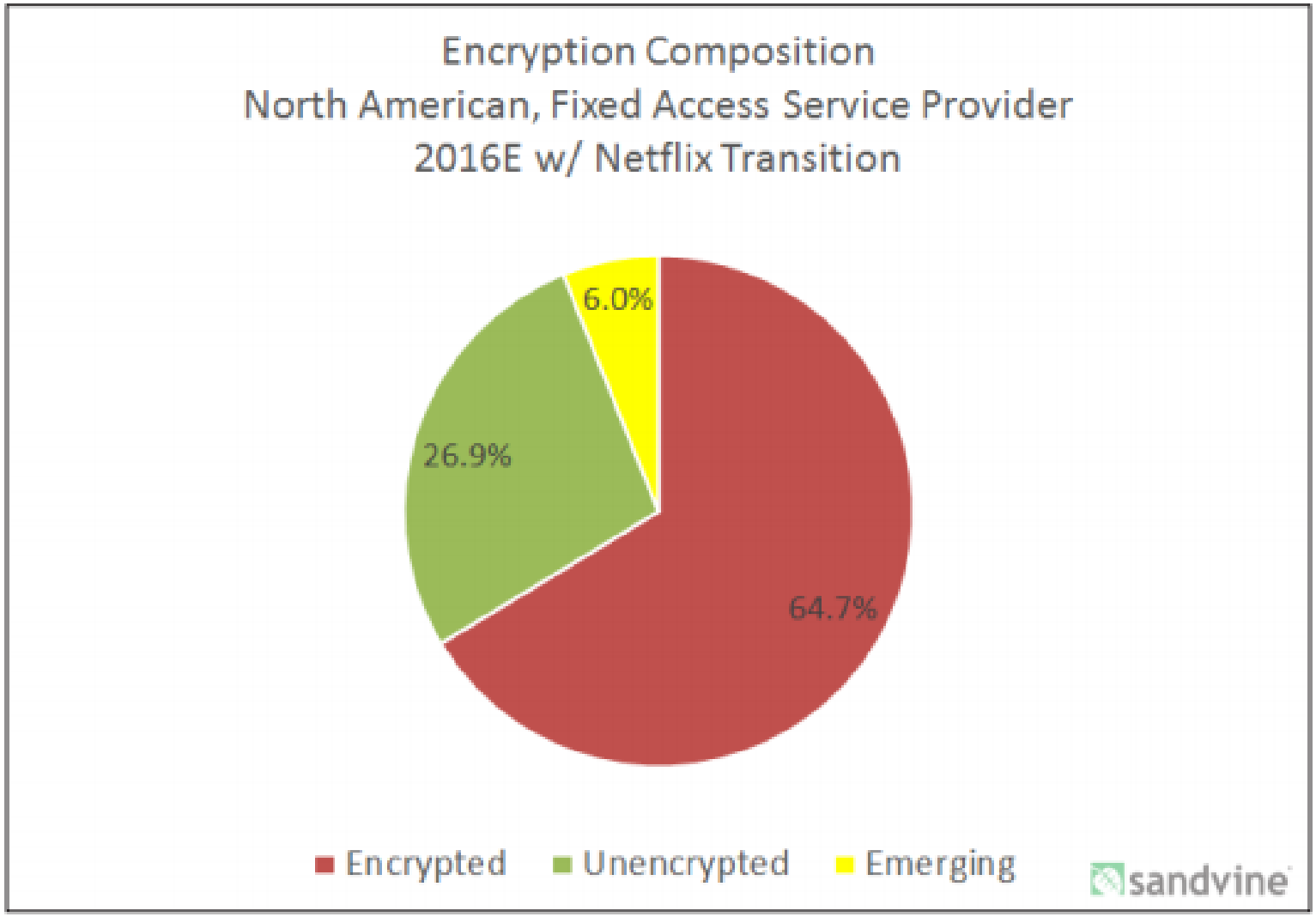


Figure 2 - Encryption Composition - North America, Fixed Access - 2016 Estimate

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**They still get the "metadata".**

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**Encrypting and authenticating content doesn't prevent any of this!**

# But "it's just metadata"!

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*"We kill people based on metadata."*

*—Michael Hayden, former director of the NSA and the CIA*

# Is "metadata" all an attacker gets?

- Common assumption: this "metadata" only includes who is talking to whom, or which website is being requested, but we assume "metadata" does include any information about the content.
- Example, interview with Jimmy Wales (Wikipedia founder):

  "***You've said that you're going to start encrypting communications on Wikipedia as a result***...

  *We have done. It's not completely finished yet but the only thing that GCHQ, hopefully, can see is that you're looking at Wikipedia. They can't see which article you're reading. It's not the government's business to know what everybody is reading."*

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- Small experiment: 10 Wikipedia pages, load one at random through HTTPS
- Attacker sniffs the network, tries to figure out which one
- In this (contrived, closed-world) scenario, it's not that hard:
  - 10 webpages have different amount of pictures
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  - This is not the only thing an attacker sees: number of requests, timings, delays, responses

# What can we do to protect our privacy?

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Report of the Special Rapporteur on the promotion and protection of the right to freedom of opinion and expression:

> *"States should promote strong encryption and anonymity. National laws should recognize that individuals are free to protect the privacy of their digital communications by using encryption technology and tools that allow anonymity online. Legislation and regulations protecting human rights defenders and journalists should also include provisions enabling access and providing support to use the technologies to secure their communications."*
>
> —*David Kaye, Report, May 2015*

# Terminology: Anonymity Set

- **Anonymity Set.** "To enable the anonymity of a subject, there always has to be an appropriate set of subjects with potentially the same attributes. Anonymity is thus defined as the state of being not identiable within a set of subjects, the anonymity set.
  The anonymity set is the set of all possible subjects. With respect to acting entities, the anonymity set consists of the subjects who might cause an action. With respect to addressees, the anonymity set consists of the subjects who might be addressed. Both anonymity sets may be disjoint, be the same, or they may overlap. The anonymity sets may vary over time."

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- **Relative Unlinkability.** "Unlinkability of two or more items of interest (e.g., subjects, messages, events, actions, ...) means that within the system (comprising these and possibly other items), from the attacker's perspective, these items of interest are no more and no less related after her observation than they were related concerning her a-priori knowledge."

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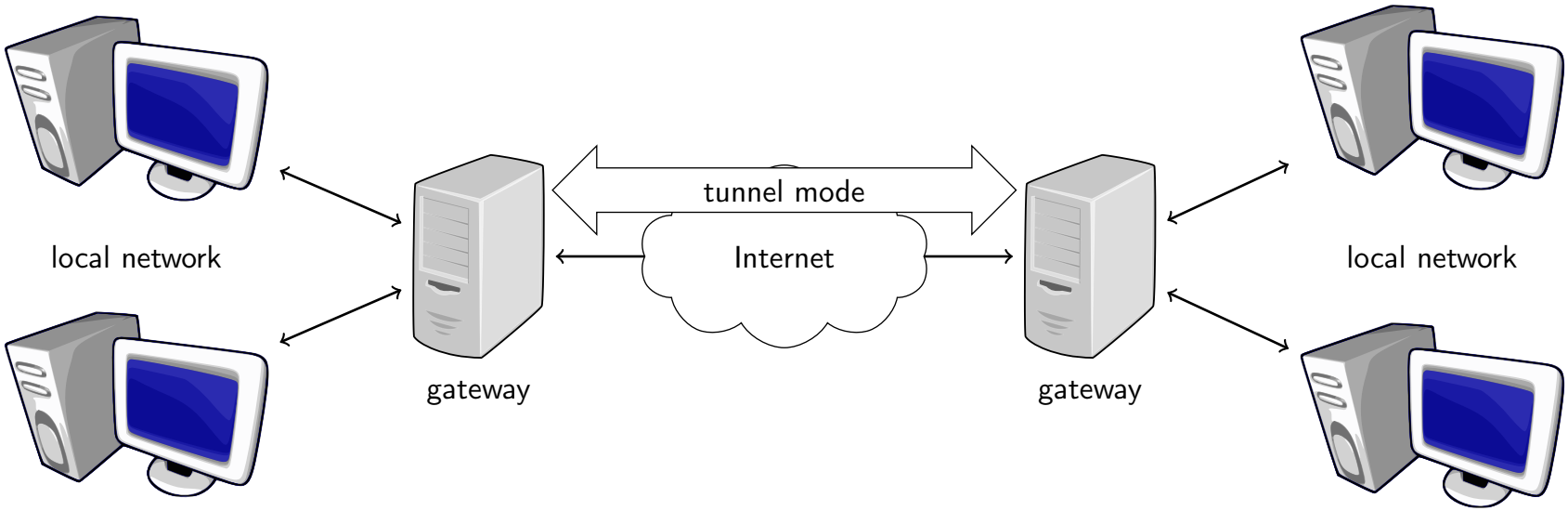
- Those that use trusted relays, i.e. the privacy/anonymity guarantees of the system rely on one centralised node.
- Those that use semi-trusted relays, i.e. compromise of any one node in the network should not degrade the privacy/anonymity of the user.

# Trusted-Relays Systems: Email

Danezis, George, and Claudia Diaz.
A survey of anonymous communication channels.
Technical Report MSR-TR-2008-35, Microsoft Research, 2008.

> *"Johan Helsingius started running a trusted mail relay, anon.penet.fi, providing anonymous and pseudonymous email accounts in 1993. The technical principle behind the service was a table of correspondences between real email addresses and pseudonymous addresses, kept by the server. Email to a pseudonym would be forwarded to the real user. Email from a pseudonym was stripped of all identifying information and forwarded to the recipient. While users receiving or sending email to a pseudonym would not be able to nd out the real email address of their anonymous correspondent, it would be trivial for a local passive attacker or the service itself to uncover the correspondence by correlating the timing of incoming and outgoing email traffic."*

# Trusted-Relay Systems: IPsec Tunneling

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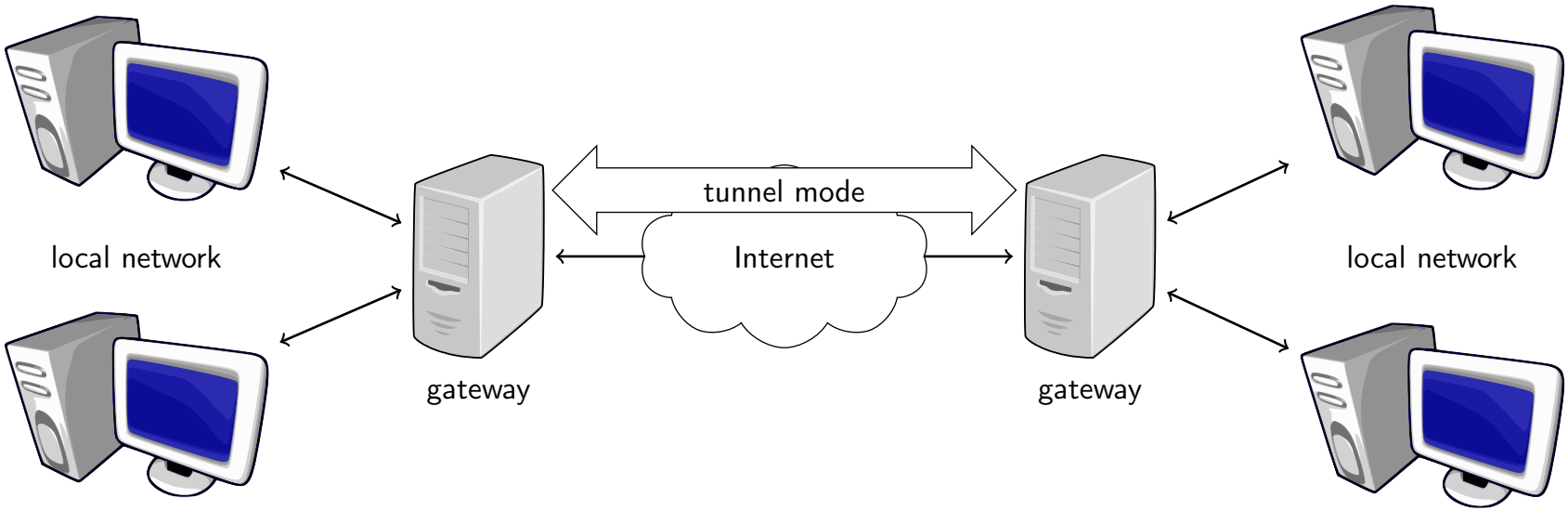


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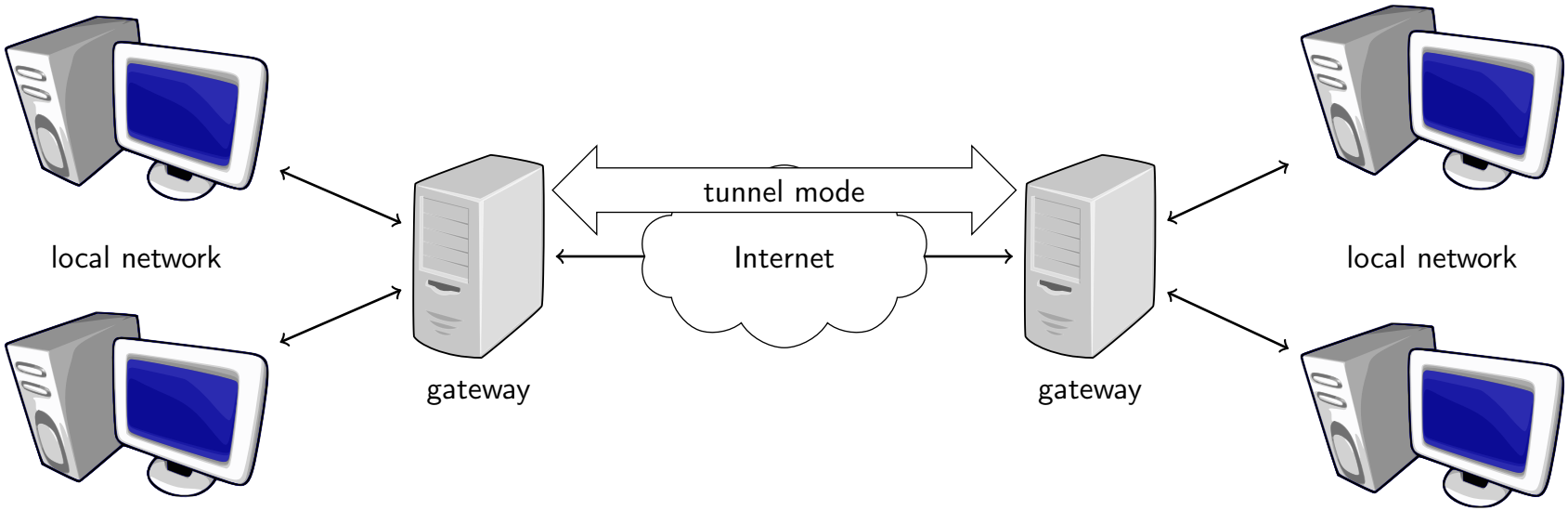


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- Problem 2: Potentially small anonymity set

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- Somewhat similar idea (without crypto): use a proxy server
- Typically: application-specific proxies (e.g., HTTP proxies) or generic request-based proxies (e.g. SOCKS proxies)
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  3. No crypto protection from the user to the proxy

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  2. Proxy somewhere in the Internet: easy to correlate ingoing/outgoing traffic
  3. No crypto protection from the user to the proxy
- Can add crypto to the proxy (e.g., OpenVPN Service)
- That still does not solve problems 1 and 2, that is: Virtual Private Networks increase user privacy but do not substantially improve anonymity. Additional problems are added: in the case of VPNs, the VPN fails open, meaning that when the tunnel to the private network breaks down, user traffic goes out in the clear.

# Trusted-Relay Systems

We can see from the previous examples that designs which place ultimate trust in any single node in the network cannot provide any strong guarantees to anonymity, because these single points of failure can be exploited (legally or otherwise) to deanonymise users.

# Trusted-Relay Systems: Mix Networks

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- Message shuffling in order to achieve unlinkability.

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- Receiver Bob decrypts and obtains $M$
- Achieves anonymity if encrypted messages are indistinguishable
- Very important: never repeat input and output!
- No protection against *tagging attacks* and *replay attacks*
- Has high communication latency (the mix should wait for enough messages to be within the mixing pool so as to provide some sufficient anonymity set for the clients)

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- Only Alice can decrypt, because only she knows both $K_X$ and $R_1$

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Chaum noted that relying on only one mix is not resilient against malicious nodes, so the function of mixing should distributed. Mixes can be chained to ensure that, even if just one of them remains honest, some anonymity is provided.

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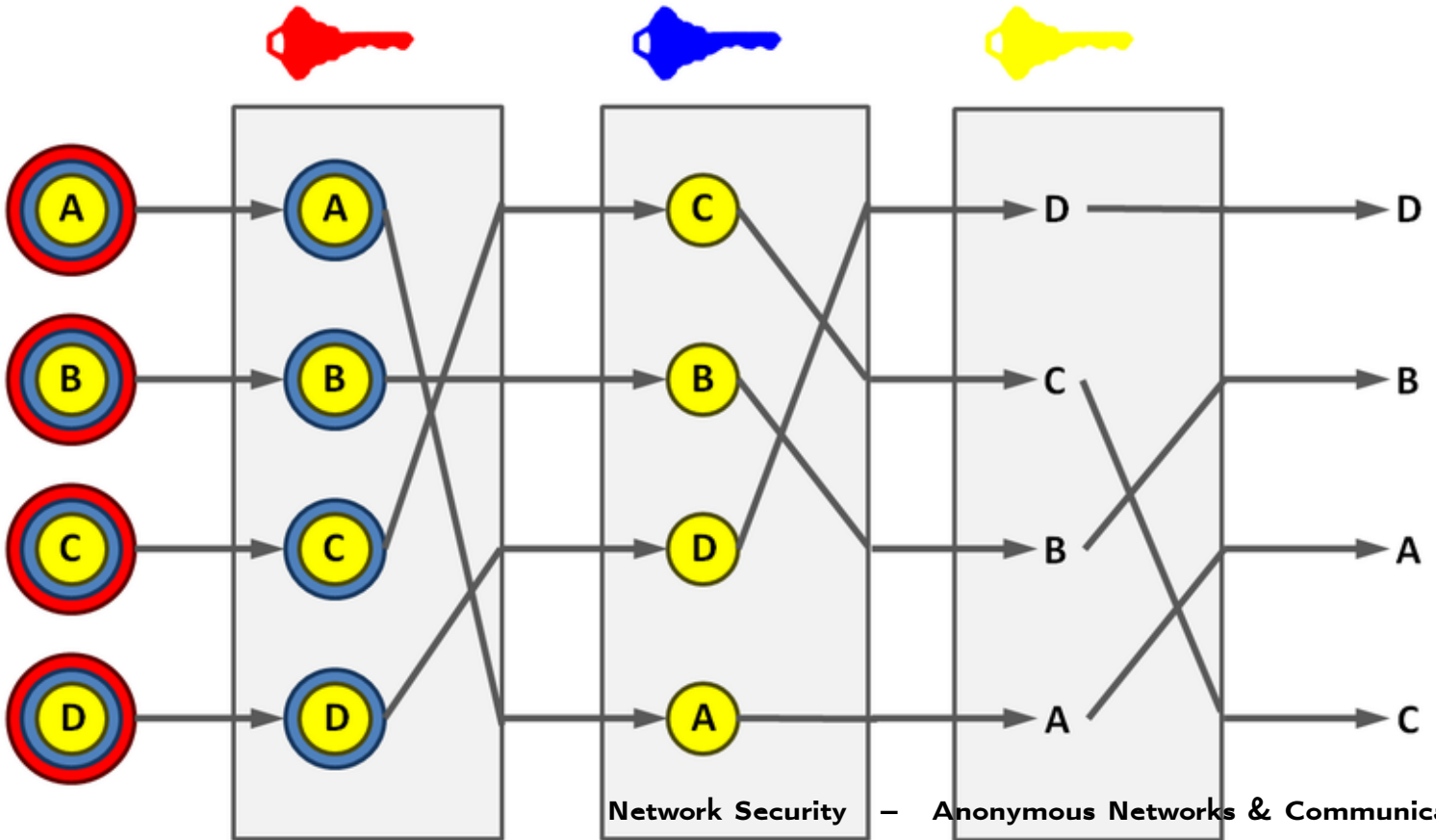
First proposed way to chain mixes together is called *cascade mixing*, and uses all nodes in the network, in a specific order:



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- These attacks rely on compromised mixes which exploit some knowledge of their position in the chain ...
- ... or multiple messages using the same sequence of mixes through the network.

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  - Allows an additional header containing a hash of the entire message.
  - Makes replies impossible to construct: the body of the reply would not be known to the creator of the anonymous address block, so it isn't possible to compute in the hash.

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**Idea of Onion Routing: Combine advantages:**

- Use cascade of "proxies", called *Tor relays* or *Tor nodes*
- Use asymmetric crypto for establishing an authenticated and encrypted channel, then use fast symmetric crypto.

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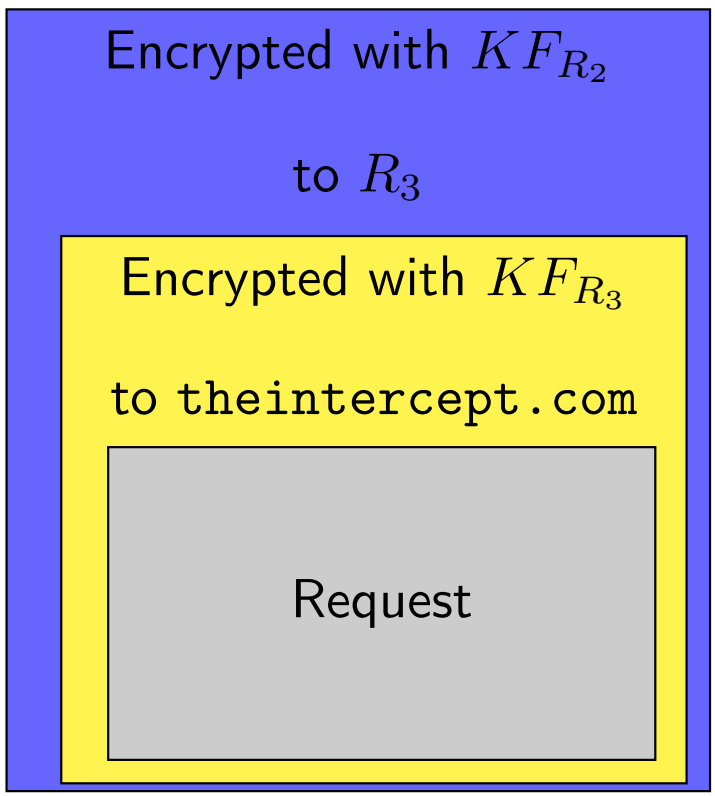


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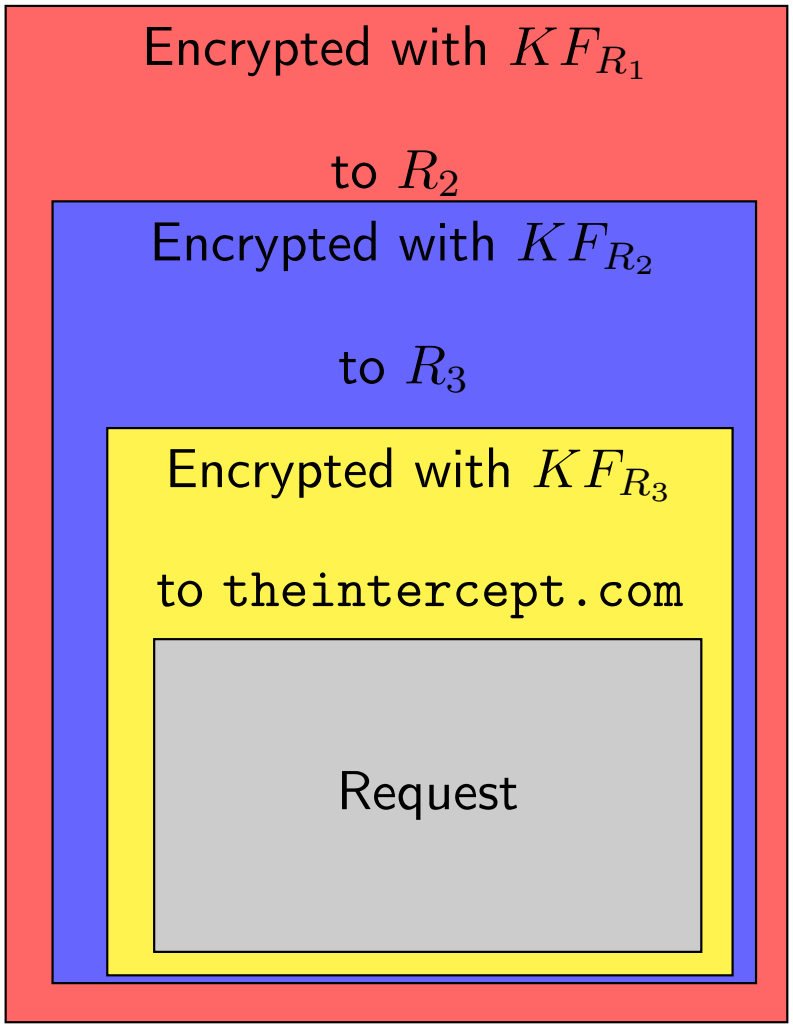


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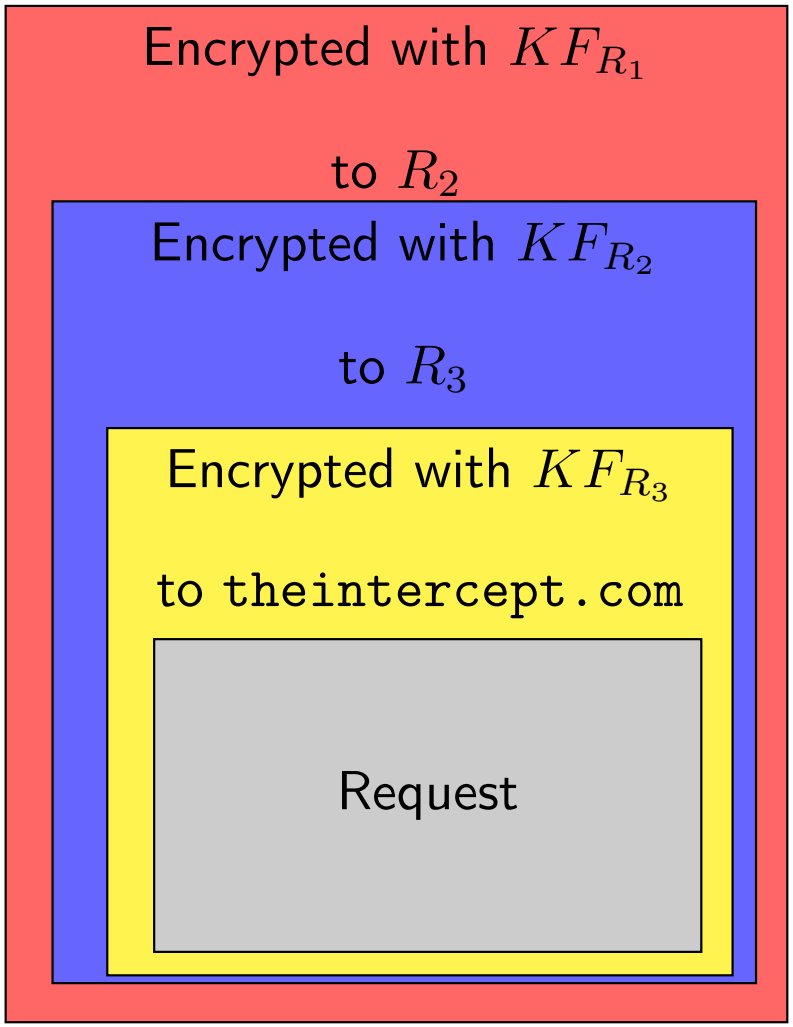


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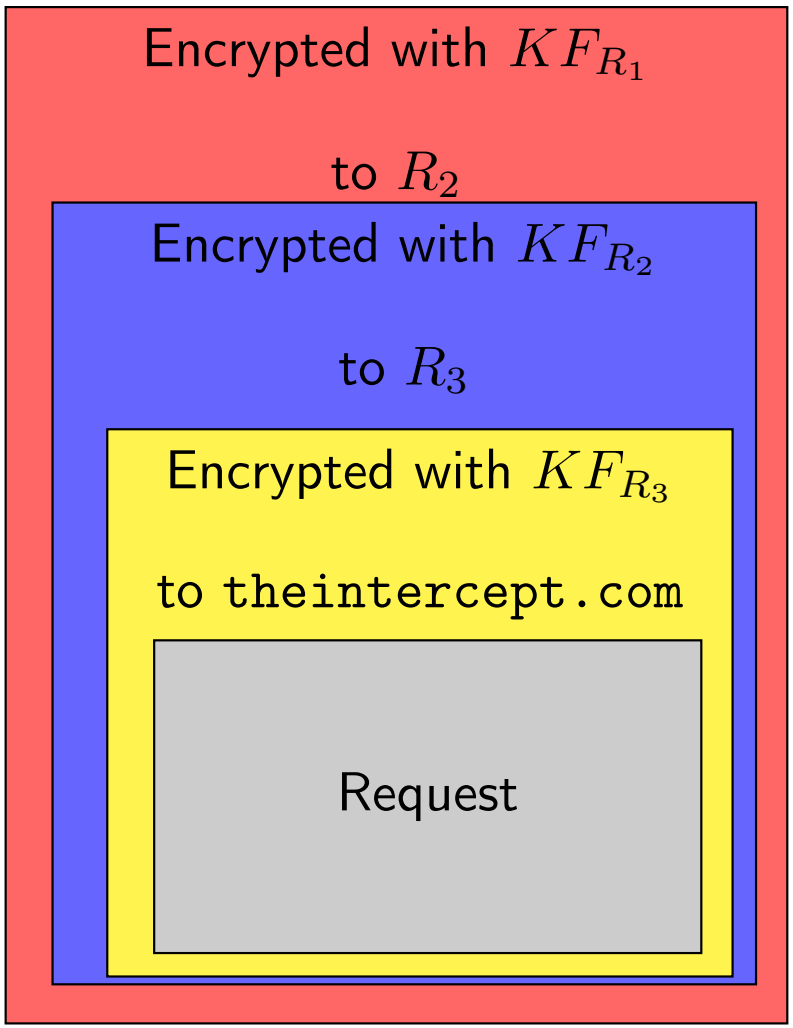


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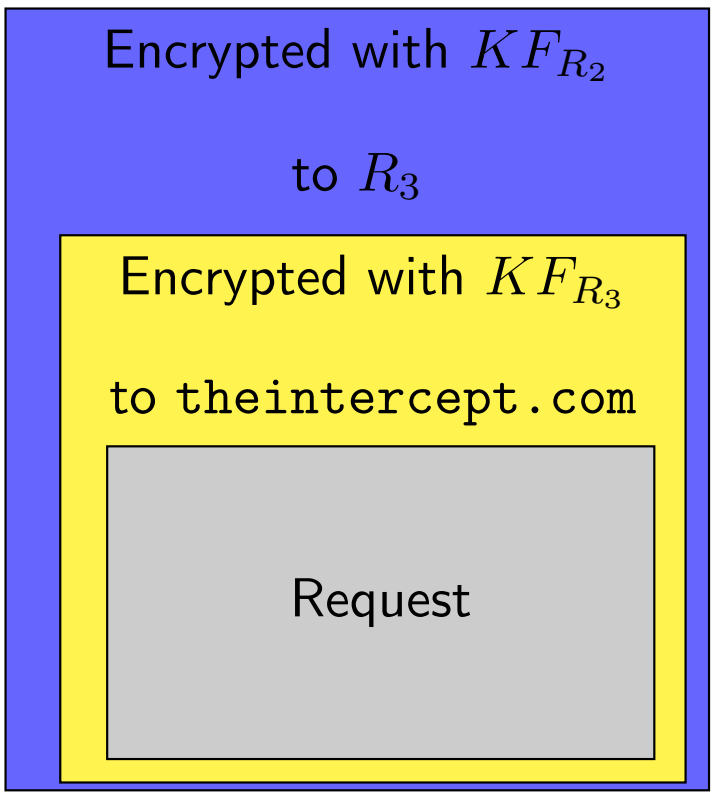


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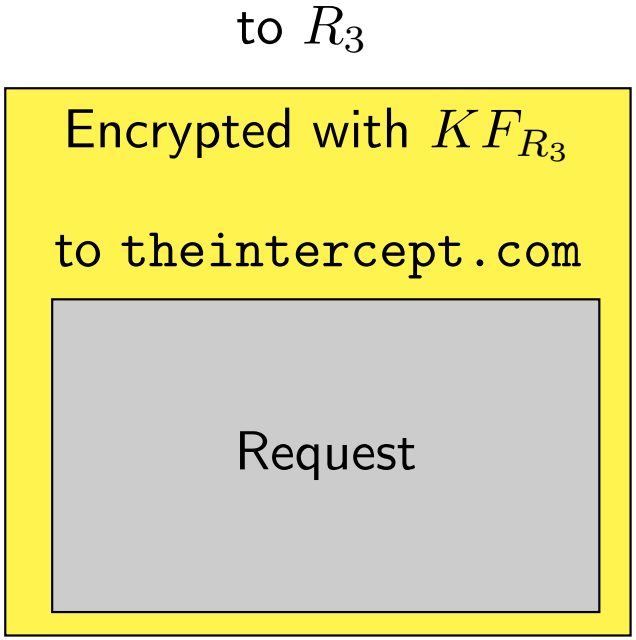


- $R_1$ receives packet, removes encryption with $KF_{R_1}$
- Sees next destination: $R_2$, forwards
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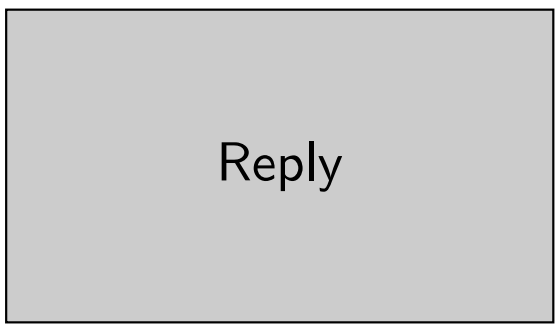
- Sees next destination: `theintercept.com`, sends request

# Response from `theintercept.com`

- $R_3$ receives reply from `theintercept.com`



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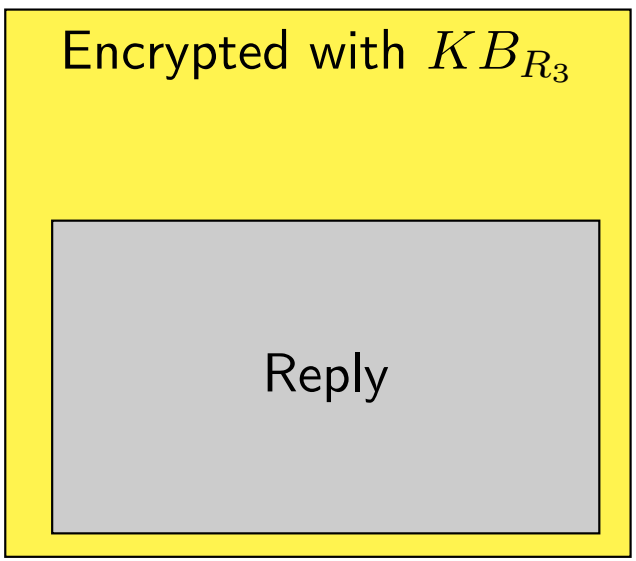


- $R_3$ receives reply from `theintercept.com`
- $R_3$ encrypts with $KB_{R_3}$, sends to $R_2$

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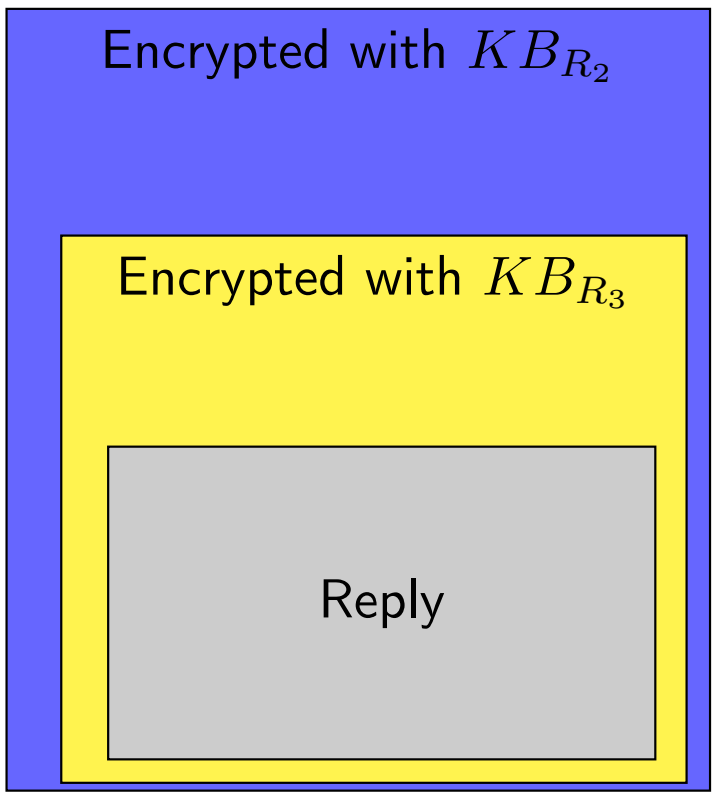


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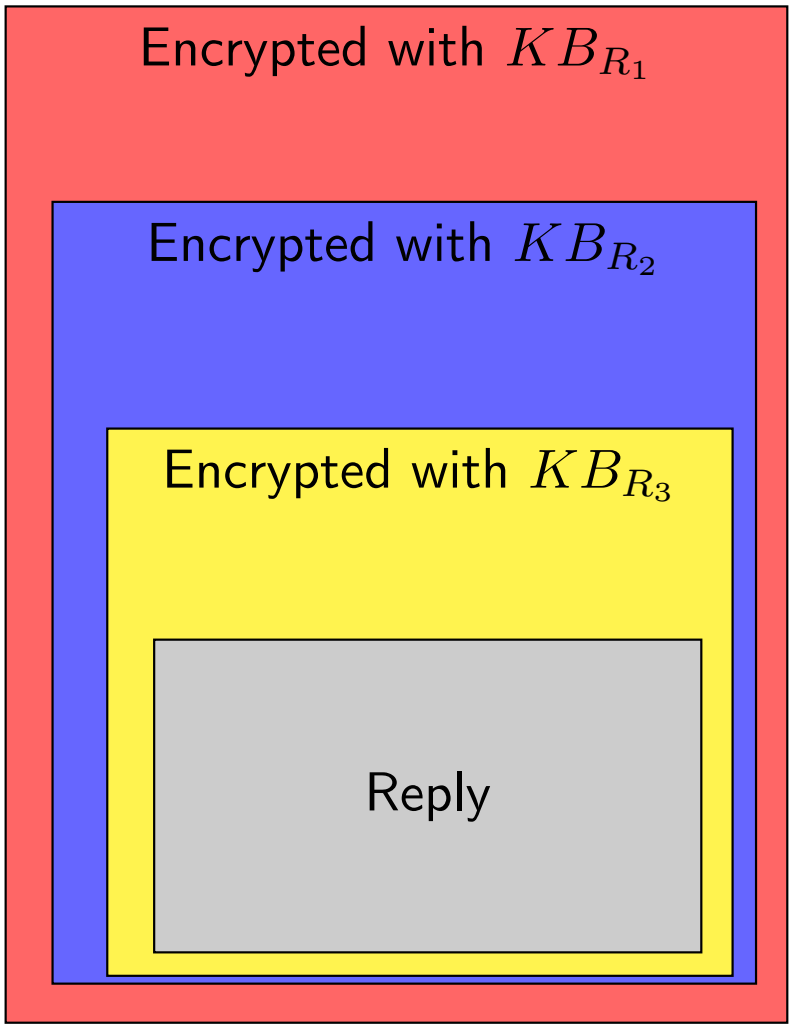


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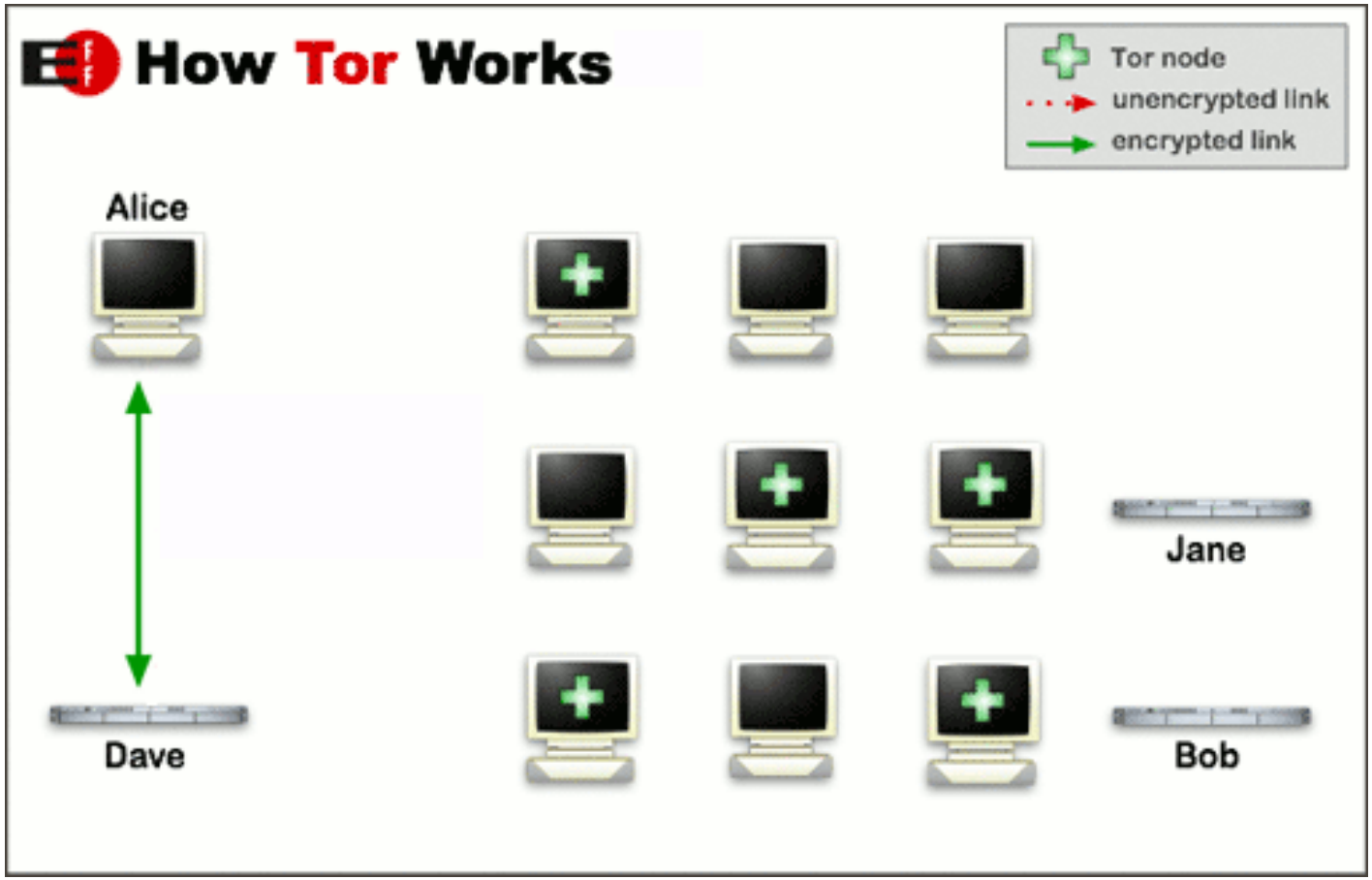
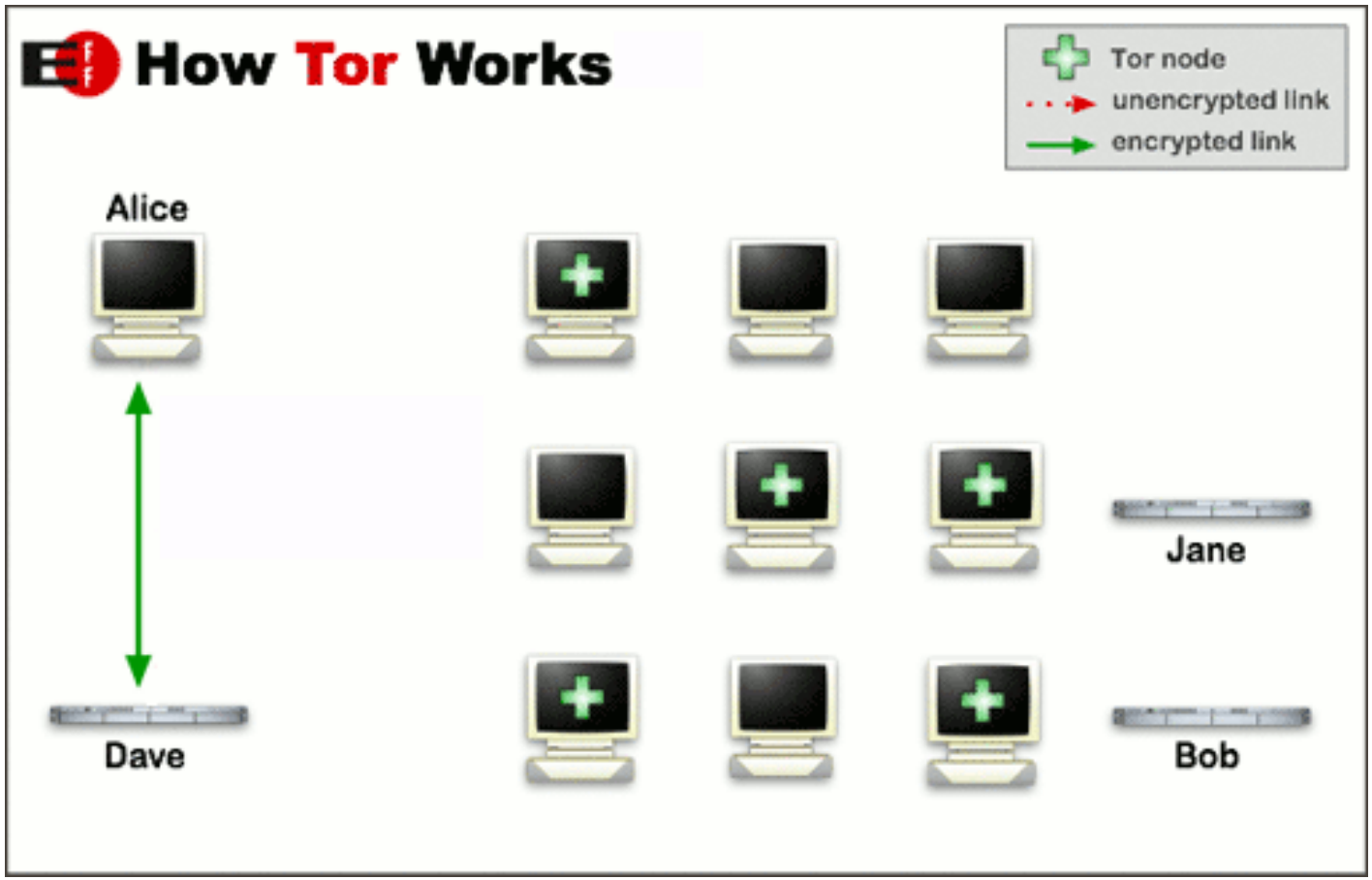
# Establishing a Circuit




Request listing of Tor nodes from Directory Authorities (DirAuths)

# Establishing a Circuit




Pick entry, middle, and exit node; obtain their public keys from directory mirror (DirServ)

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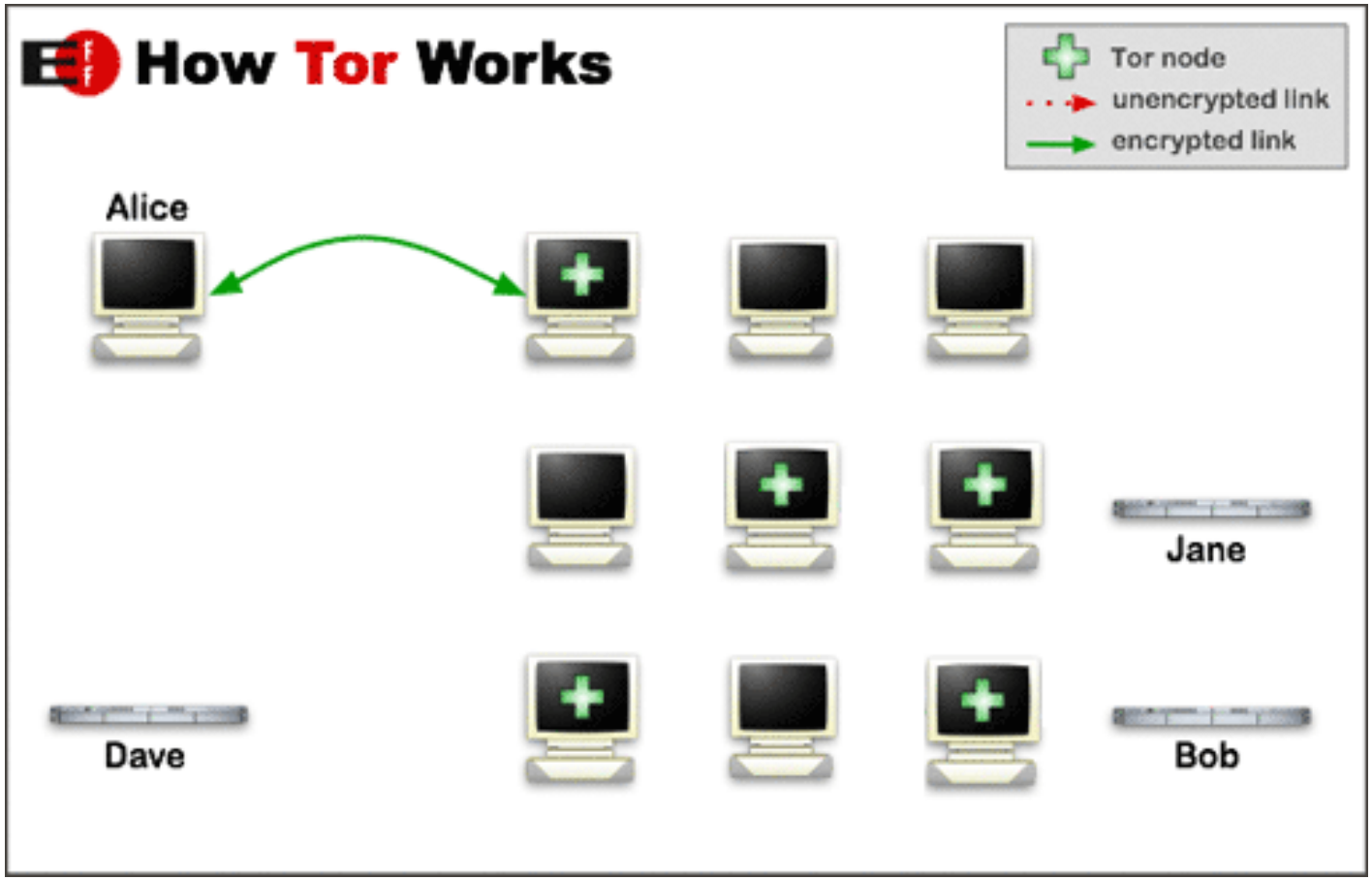


Exchange symmetric key with entry node (Diffie-Hellman)

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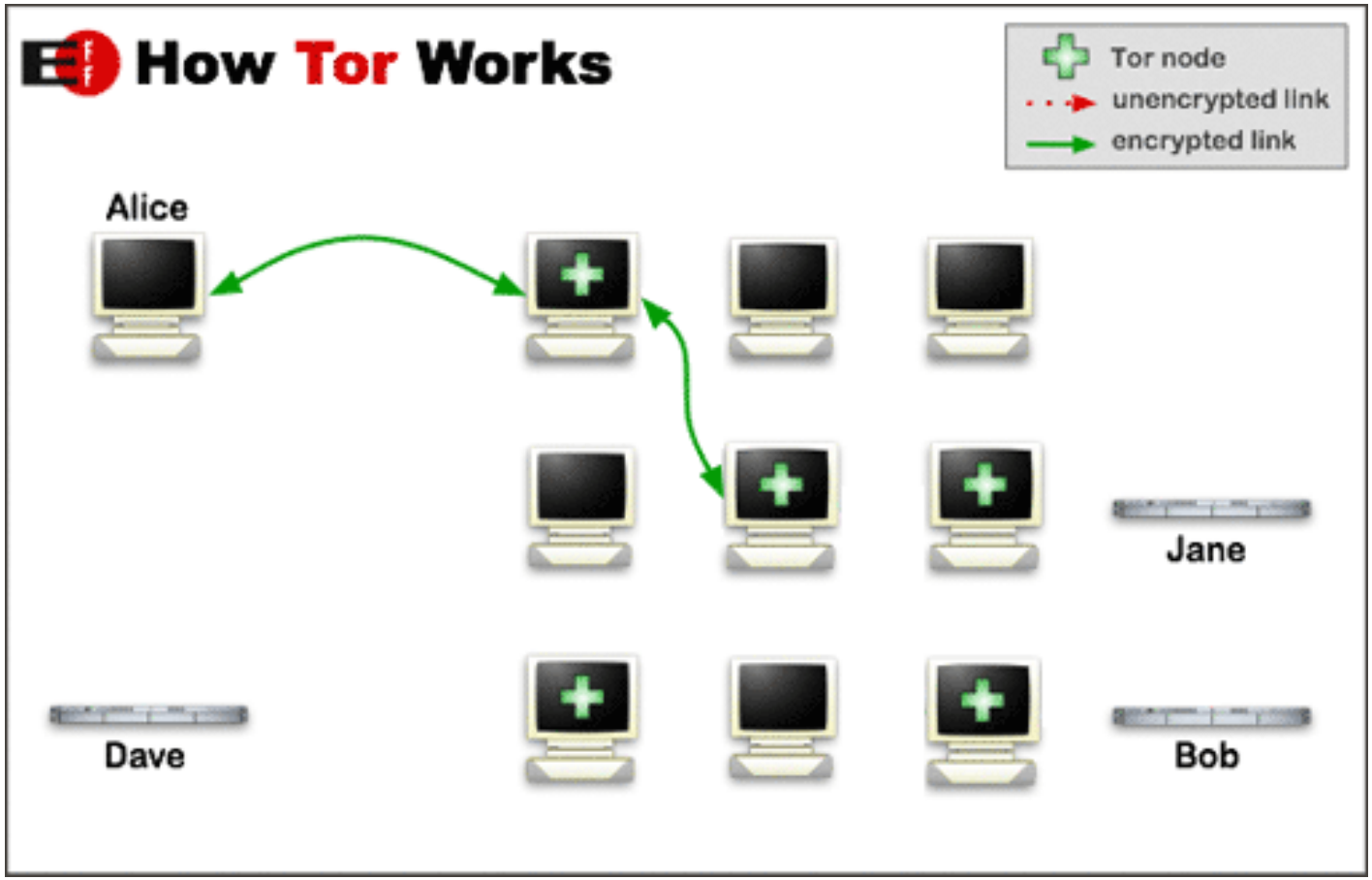


Exchange key with middle node (tunnelled through entry node)

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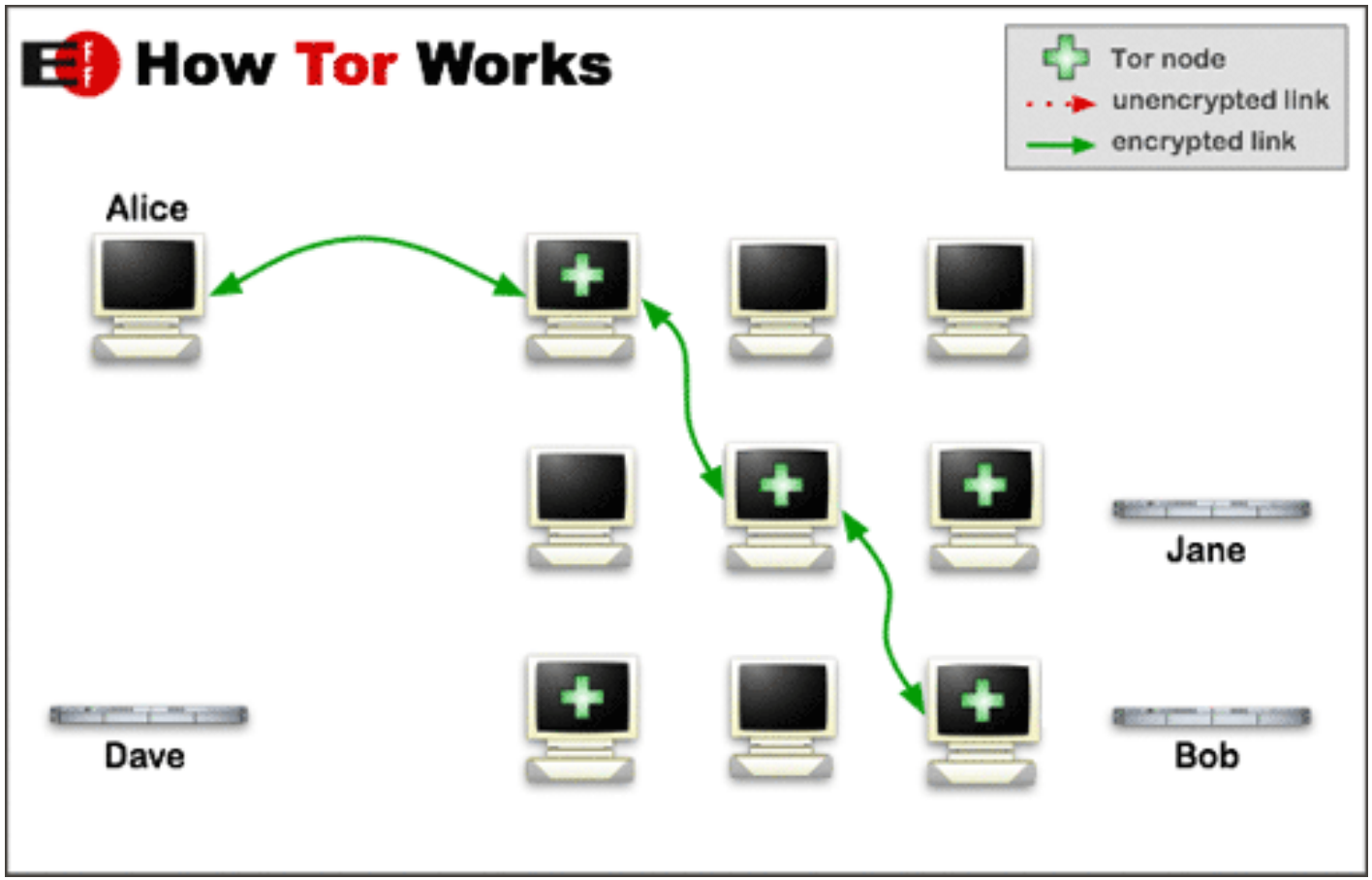


Exchange key with exit node (tunnelled through middle node, tunnelled through entry node)

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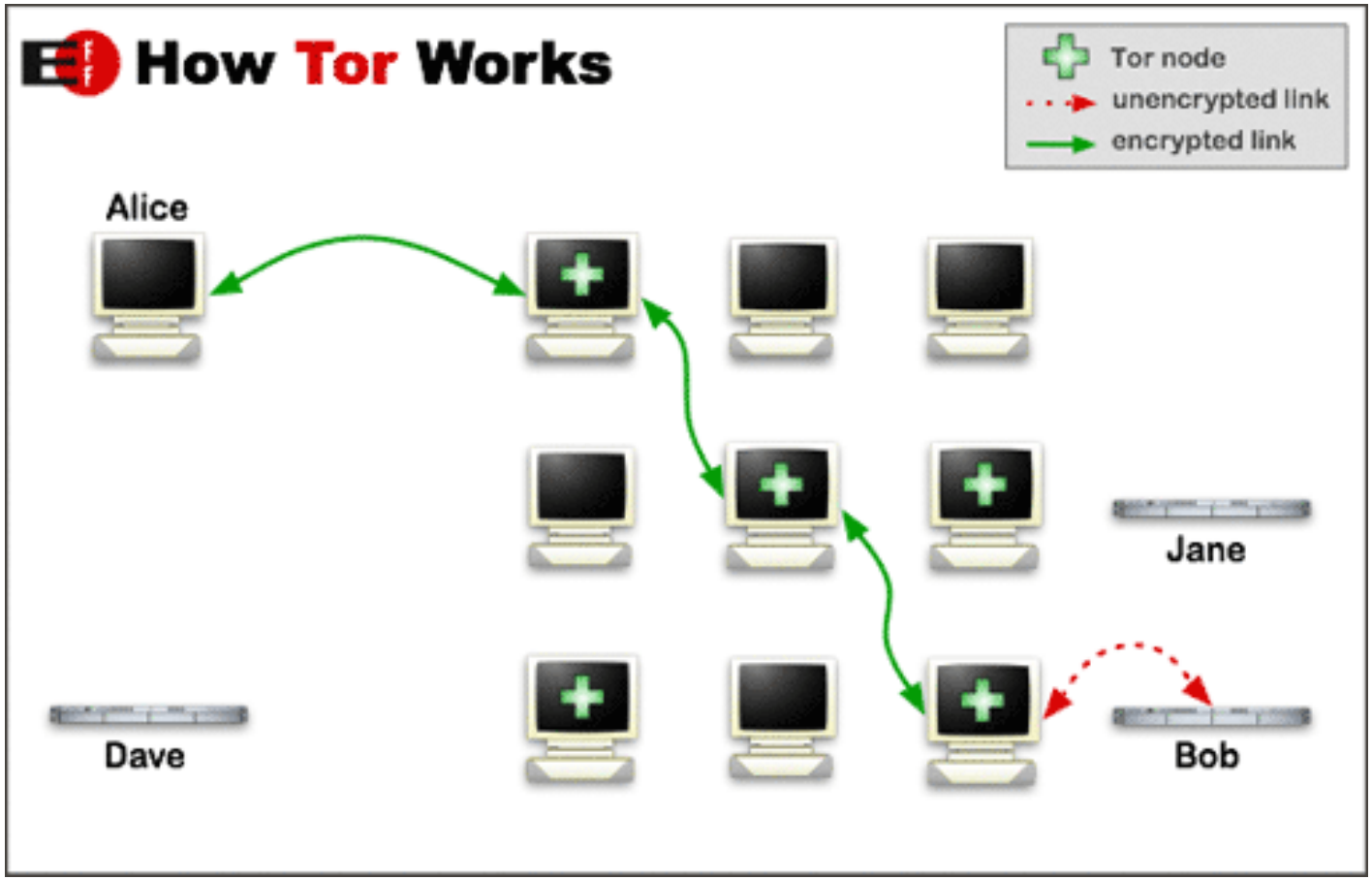


Communicate with Bob (`theintercept.com`)

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- If you transparently proxy several applications through Tor simultaneously, and one leaks your IP address (bad apple attack), this activity may be linkable to the activity of other applications and decrease anonymity.

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  - CMU researchers simultaneously did a *Sybil attack* by running several high-bandwidth relays in both entry and exit positions.

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- *Timing correlation attacks* are still theoretically possible:
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  - Correlate traffic going into and out of this proxy
- Tor currently doesn't really do padding:
  - There are patches for the upcoming (0.2.8) version to use padding in the outer TLS connection layer (not circuit-layer), in order to decrease the resolution of timing correlation attacks in netflow records.
  - There are plans to implement adaptive padding techniques (see the "WTF-PAD" paper) at the circuit-level in the future to defend against *website traffic fingerprinting* correlation attacks.

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- Quotes from these slides:

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  *"With manual analysis we can de-anonymize a **very small fraction** of Tor users, however **no** success de-anonymizing a user in response to a TOPI request/on demand."*

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- Not-so-secretly, we think the NSA stinks too. :P

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- Can also use Tor to circumvent country filters:
  - Need an IP address that isn't in Germany (e.g. because of GEMA restrictions on YouTube): can use Tor access YouTube from a non-German IP address.

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  - visiting `https://bridges.torproject.org/`
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- Yes, that whole system sucks. One of my current projects is redesigning and rewriting it.

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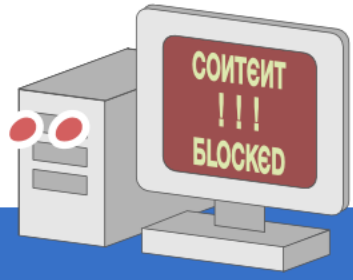
  - has a characteristic packet-size distribution
- Solution: disguise Tor traffic as other traffic
- Pluggable Transport API allows communication between obfuscating SOCKS proxy and Tor client

★ YOU ★

Can Help Protect

Freedom Of Speech

Online...




Run a

TOR RELAY

Today!

★ ★ TorProject.org ★ ★