Anonymity Analysis of TOR in Omnet++

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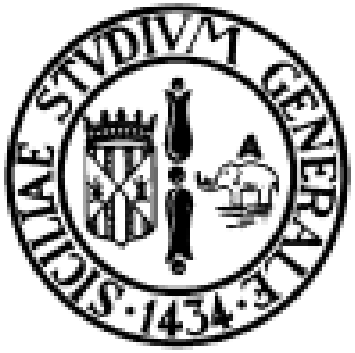
"Security in Mobility"



Introduction: what's Anonymity?

What's Anonymity?

- Anonymity is the state of being anonymous, not known by others.

Who needs anonymity, and why?

- Journalists, Dissidents, Whistle blowers
- Censorship resistant publishers/readers
- Socially sensitive communicants
  - Chat rooms and web forums for abuse survivors, people with illnesses
- Law Enforcement
  - Anonymous tips or crime reporting
  - Surveillance and honeypots

Introduction: what's Anonymity?

Who needs anonymity, and why?

- **You:**
  - Where are you sending email (who is emailing you)
  - What web sites are you browsing
  - Where do you work, where are you from
  - What do you buy, what books do you read, ...

Introduction: what's Anonymity?

Who needs anonymity, and why?

- **And yes, criminals:**

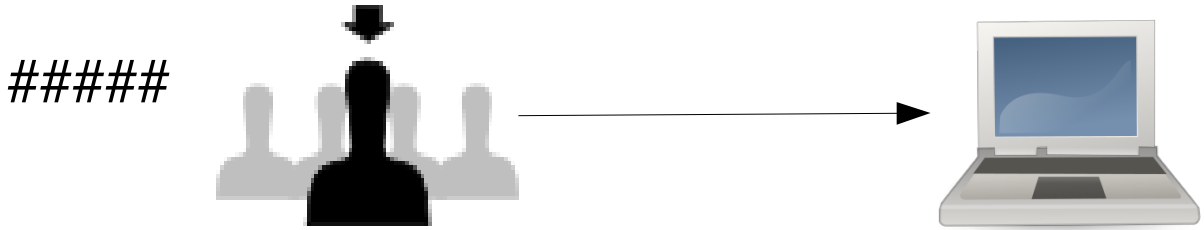
But they already have it.
We need to protect everyone else.

Introduction: what's Anonymity?

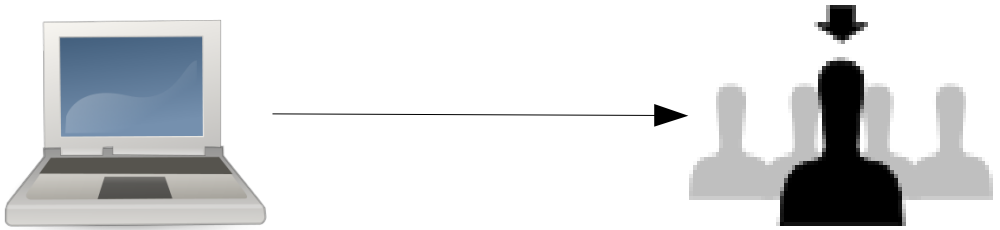
Anonymity in the Internet:

Let Alice would communicate with Bob

forward anonymity: no one could know who Alice is



reverse (or backward) anonymity: no one could know who Bob is



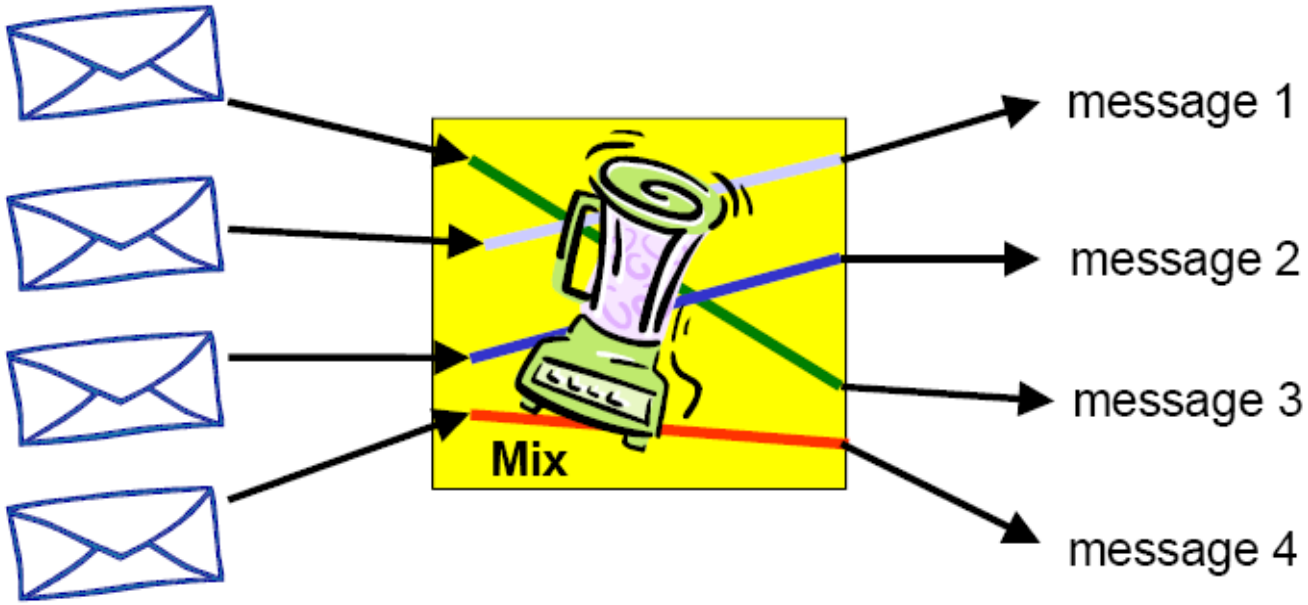
Introduction: How To Achieve Anonymity

Mainly used approach:

- **Mixing**
- **Proxy**

Introduction: How To Achieve Anonymity

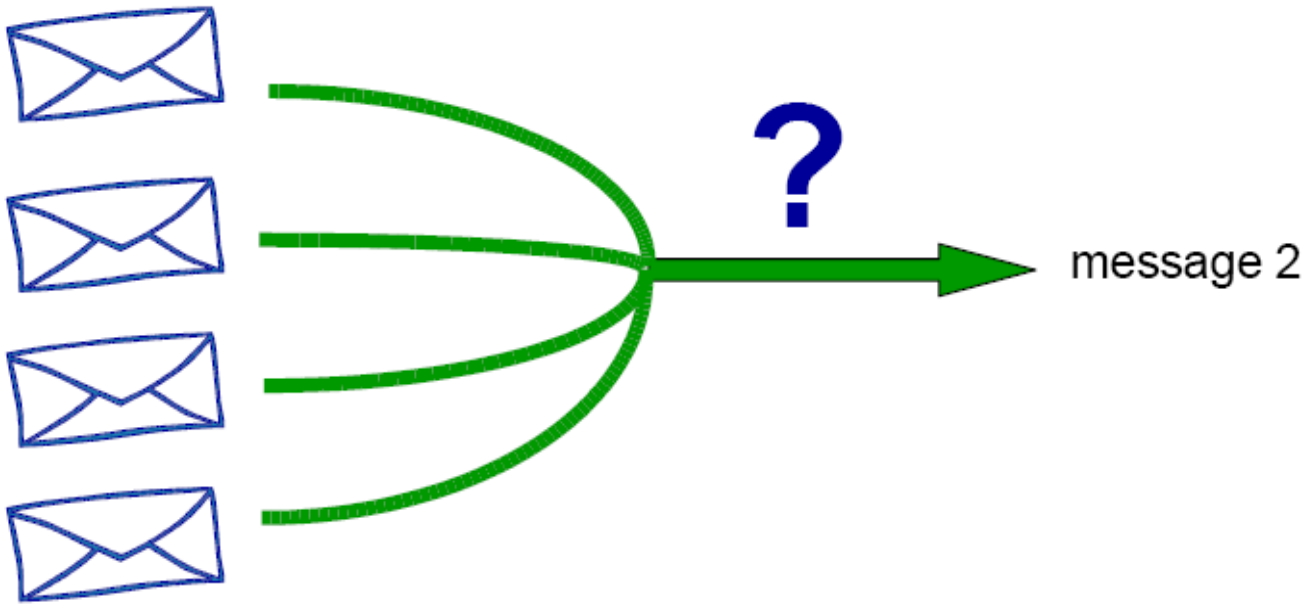
What does a mix do?



Randomly permutes and decrypts input.

Introduction: How To Achieve Anonymity

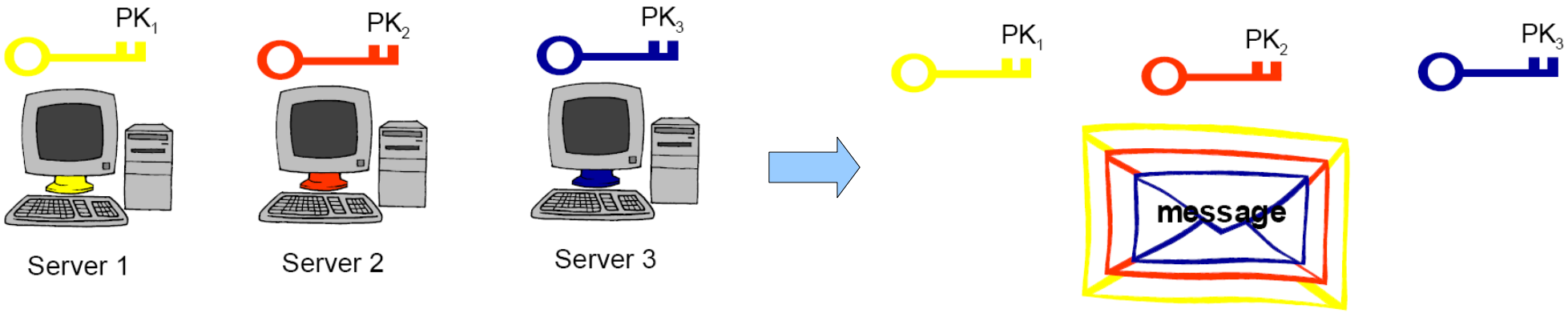
What does a mix do?



Adversary can't say which cyphertext corresponds to a given message

Introduction: How To Achieve Anonymity

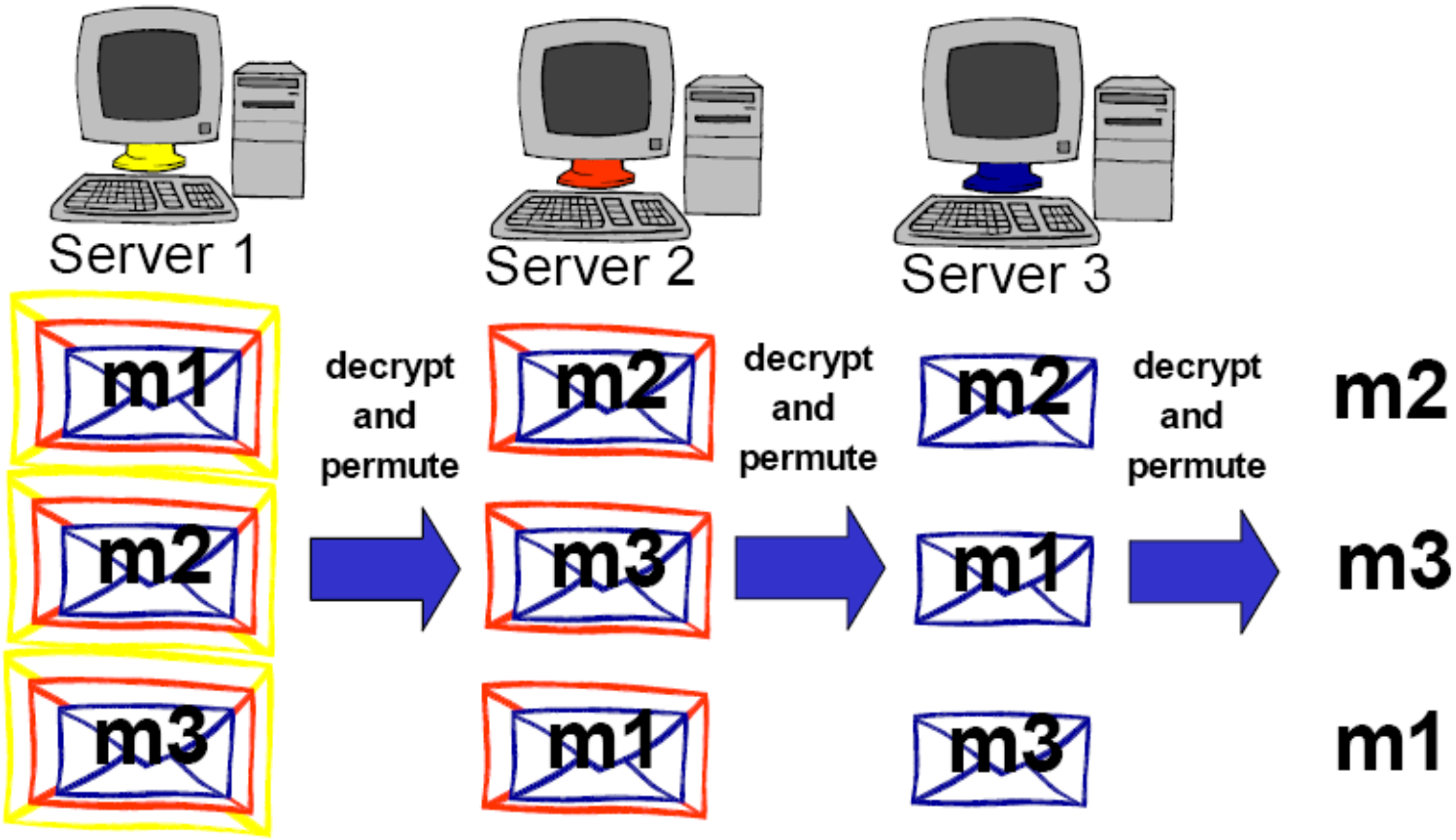
What does a mix do?



Each server have a Key, they encrypt the message with layer of crypto like an *onion*

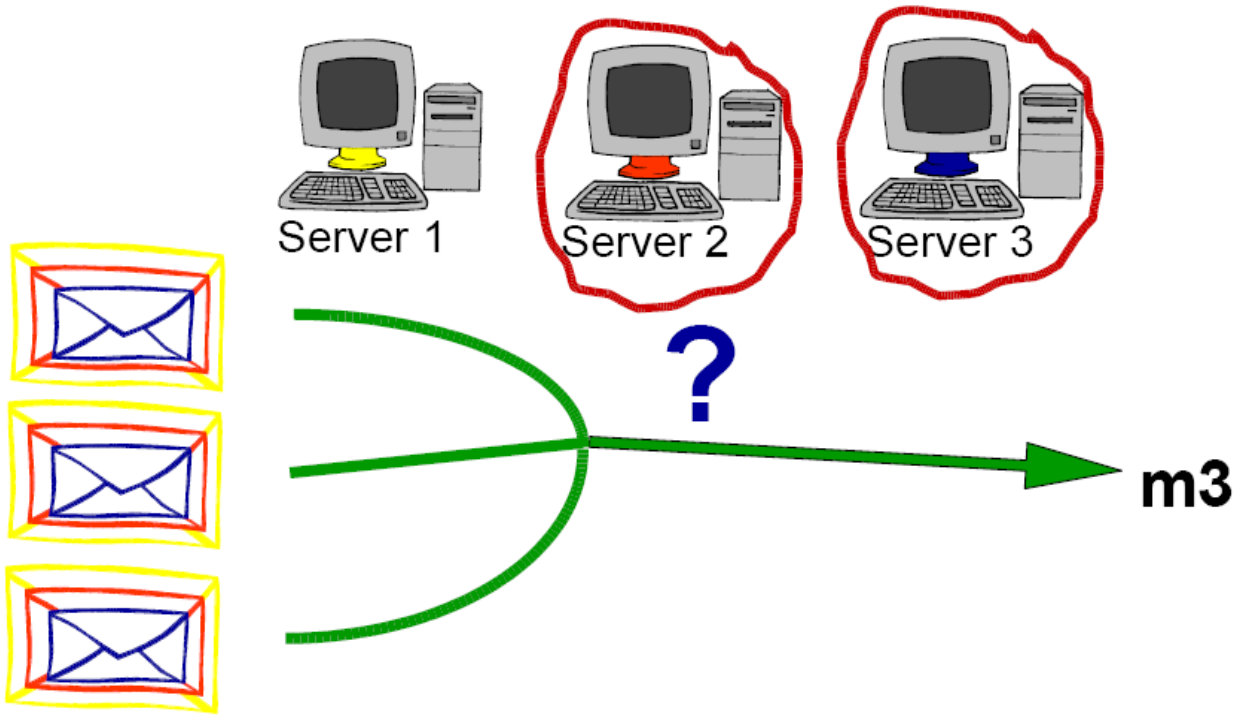
Introduction: How To Achieve Anonymity

What does a mix do?



Introduction: How To Achieve Anonymity

What does a mix do?



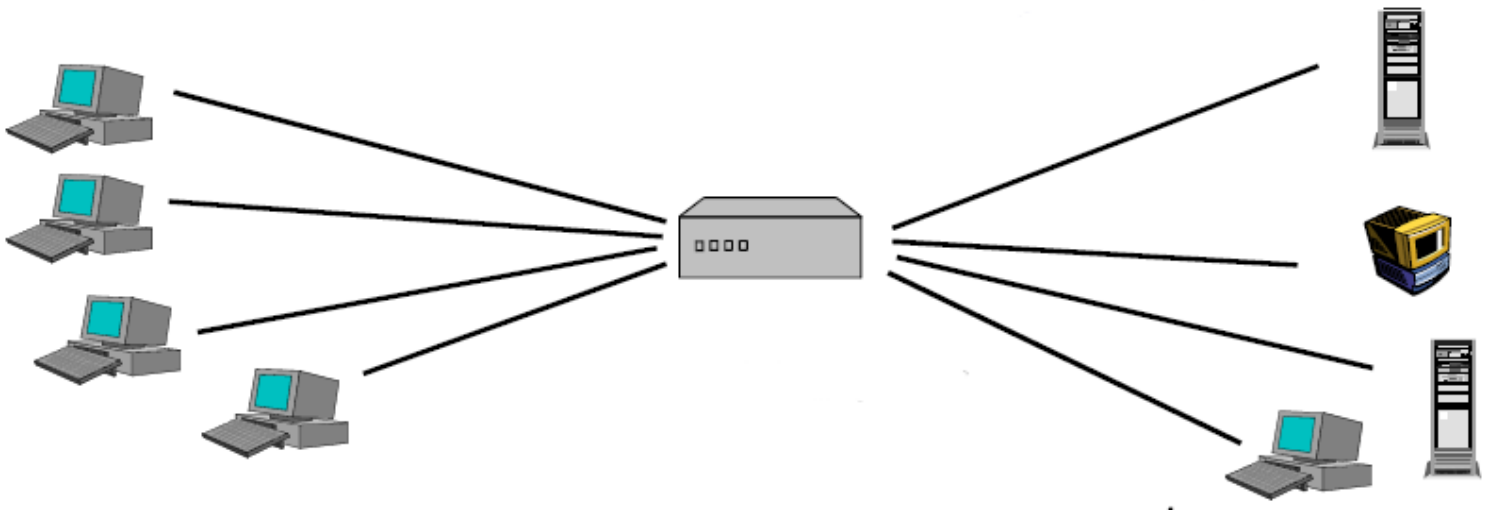
One honest server preserve anonymity

Introduction: How To Achieve Anonymity

But if we need quick interaction?

Introduction: How To Achieve Anonymity

Anonymizing Proxy



- Communications appears to come from the proxy, not from the real hosts
- Advantage: Simple, Focuses lots of traffic for more anonymity

- Disadvantage: Single point of failure, compromise, attack

Introduction: Tor – The Onion Router

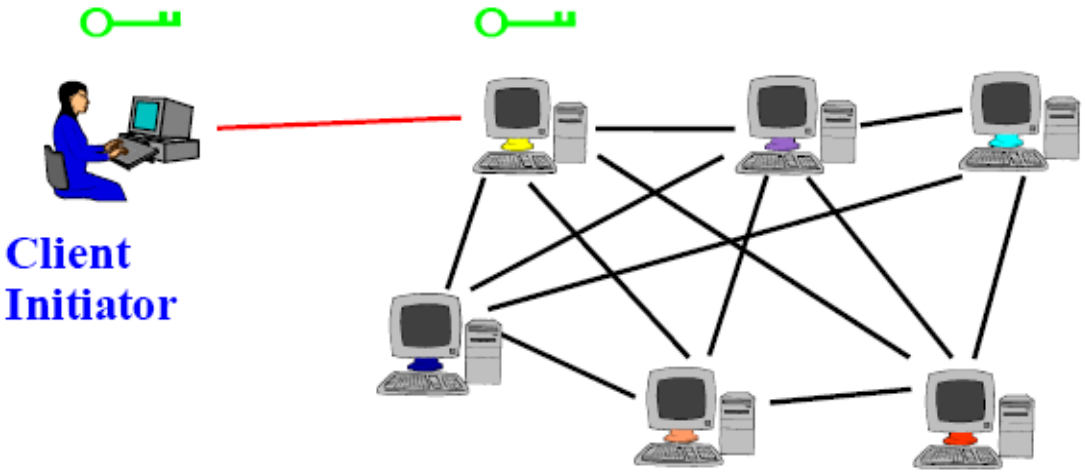
Let's use the advantage of both the approach:

- Use public key crypto to establish the circuit
- Use symmetric key crypto to move the data
  - Like SSL - TLS based proxies
- Distributed trust like mixes

TOR: THE ONION ROUTER

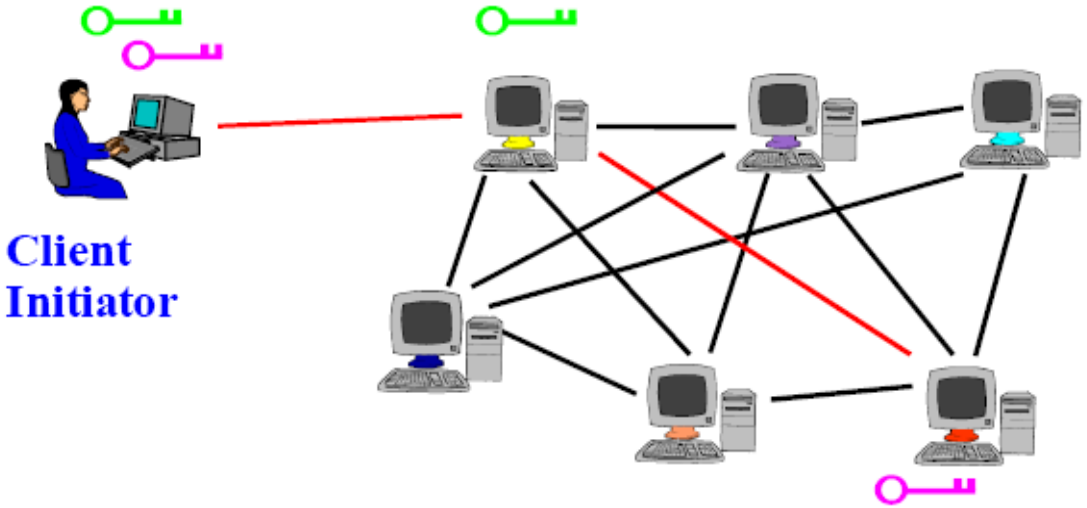
How Tor work: Circuit Setup

- Client proxy establish session key + circuit with the Onion Router 1



How Tor work: Circuit Setup

- Client proxy establish session key + circuit with the Onion Router 1
- Proxy tunnels through that circuit to extend to Onion Router 2



How Tor work: Circuit Setup

- Client proxy establish session key + circuit with the Onion Router 1
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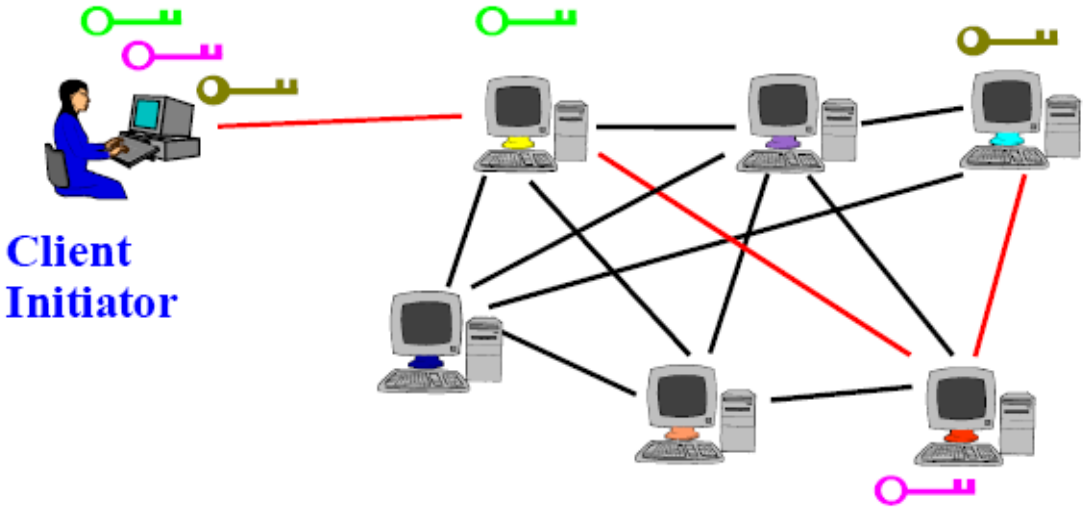
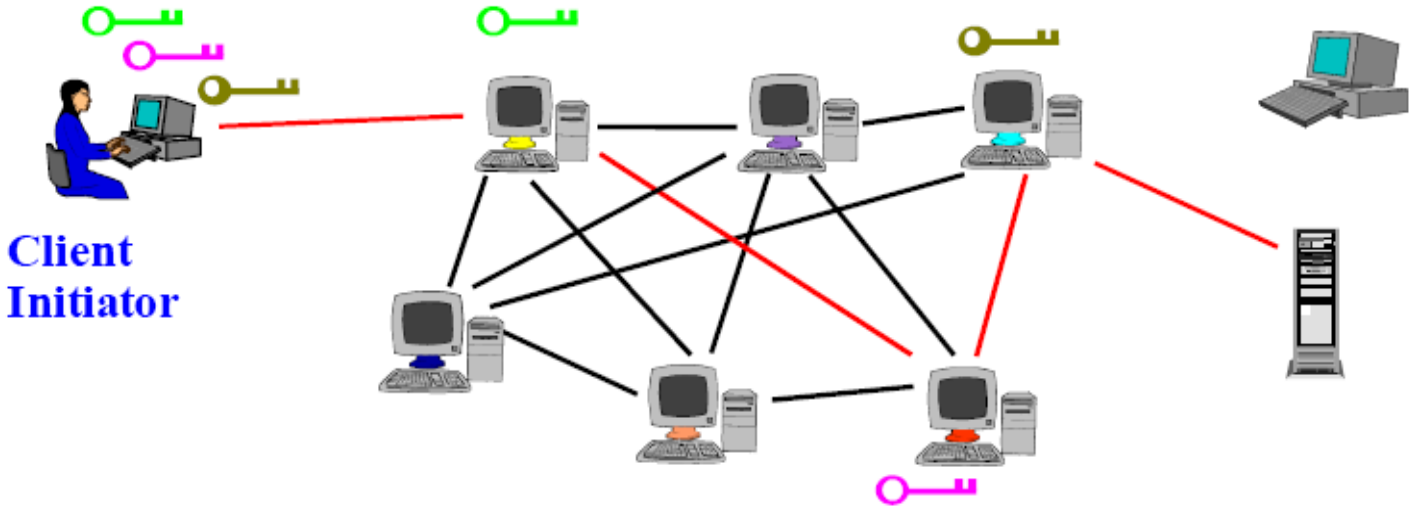
- Etc ...



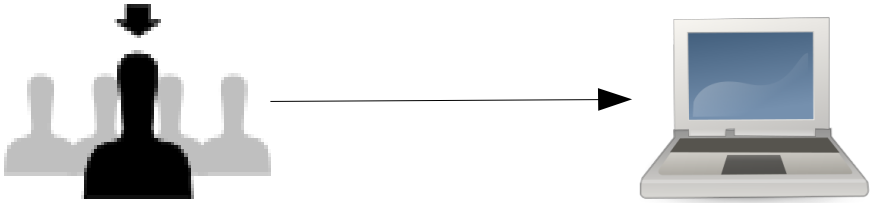
How Tor work: Circuit Setup

- Client proxy establish session key + circuit with the Onion Router 1
- Proxy tunnels through that circuit to extend to Onion Router 2
- Etc...
- Client application connect and communicate over the TOR circuit

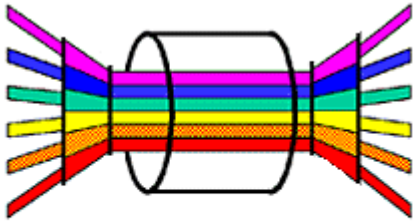


How Tor work: Feature

- Perfect *forward anonymity*
  - Incremental building of circuit thought session key negotiation with each next node.
  - Periodic renewal of circuit

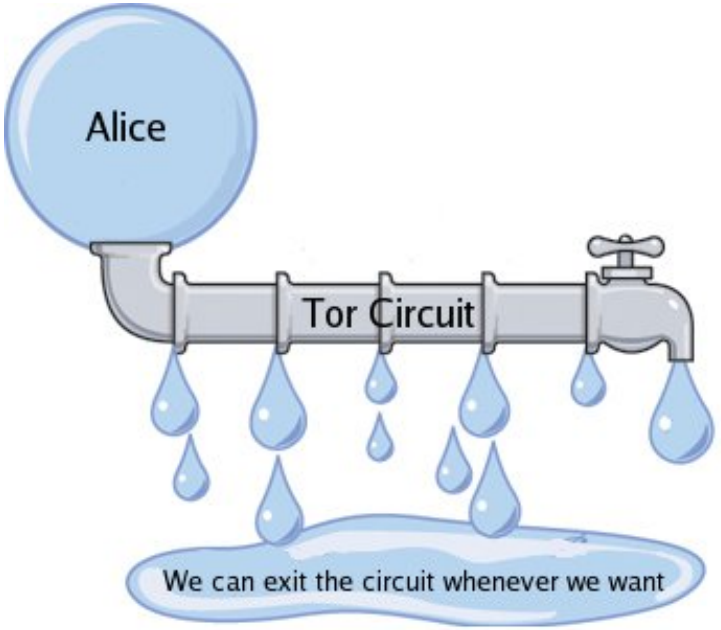


- We can multiplex more TCP streams in one circuit to reduce latency

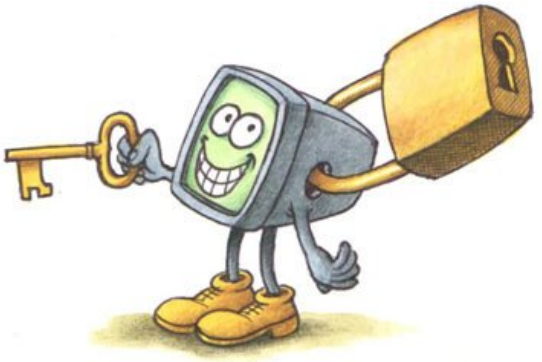


How Tor work: Feature

- Leaky pipe topology (no end-to-end attack)



- TLS in every transaction between nodes
  - Can't modify data in transit
  - Impossibility of portray a Router



How Tor *in depth* works: Overview – What?

Tor is a Open Source Program, written in ANSI C.
The project was in origin developed by the U.S. Army, then donated to the Open Source Community.
It lives thanks to the care of million of people, and operate thanks to the bandwidth donated by normal people who set up a TOR node.
The more we are, the better anonymity we could have!!!

OSI certified

How Tor work: Feature - How?

But ... how TOR can do this ???

```
/* Copyright (c) 2001 Matej Pfajfar.
 * Copyright (c) 2001-2004, Roger Dingledine.
 * Copyright (c) 2004-2006, Roger Dingledine, Nick Mathewson. */
/* See LICENSE for licensing information */
/* $Id: onion.c 8479 2006-09-24 17:20:41Z nickm $ */
const char onion_c_id[] =
  "$Id: onion.c 8479 2006-09-24 17:20:41Z nickm $";

/**
 * \file onion.c
 * \brief Functions to queue create cells, and handle onionskin
 * parsing and creation.
 **/

#include "or.h"

/** Type for a linked list of circuits that are waiting for a free CPU worker
 * to process a waiting onion handshake. */
typedef struct onion_queue_t {
  circuit_t *circ;
  time_t when_added;
  struct onion_queue_t *next;
} onion_queue_t;

/** 5 seconds on the onion queue til we just send back a destroy */
#define ONIONQUEUE_WAIT_CUTOFF 5

/** Global (within this file) variables used by the next few functions */
static onion_queue_t *ol_list=NULL;
static onion_queue_t *ol_tail=NULL;
/** Length of ol_list */
```

How Tor *in depth* works: Overview

```c
/* Copyright (c) 2001 Matej Pfajfar.
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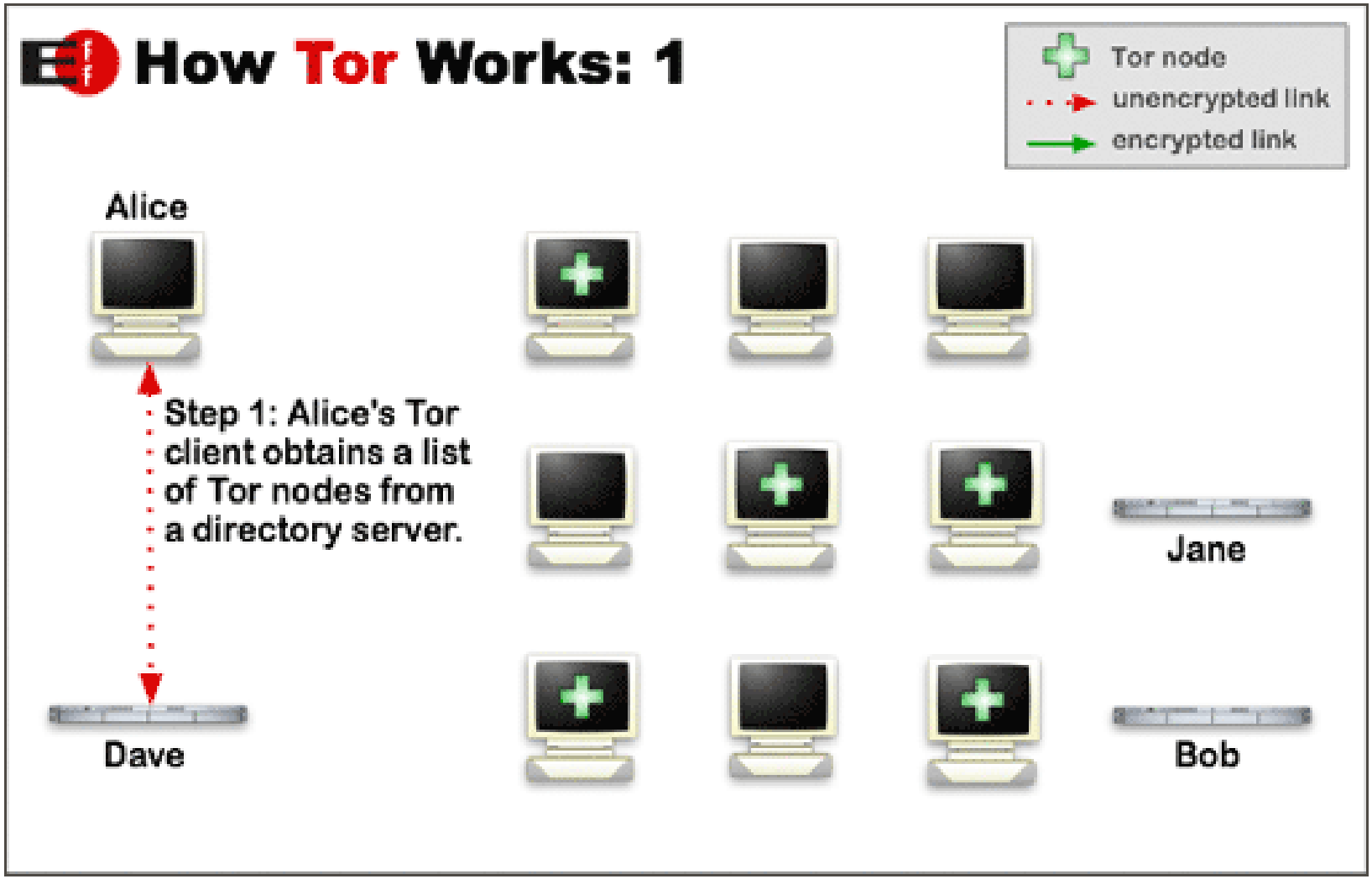
Let's see it in depth!

How Tor *in depth* works: Overview



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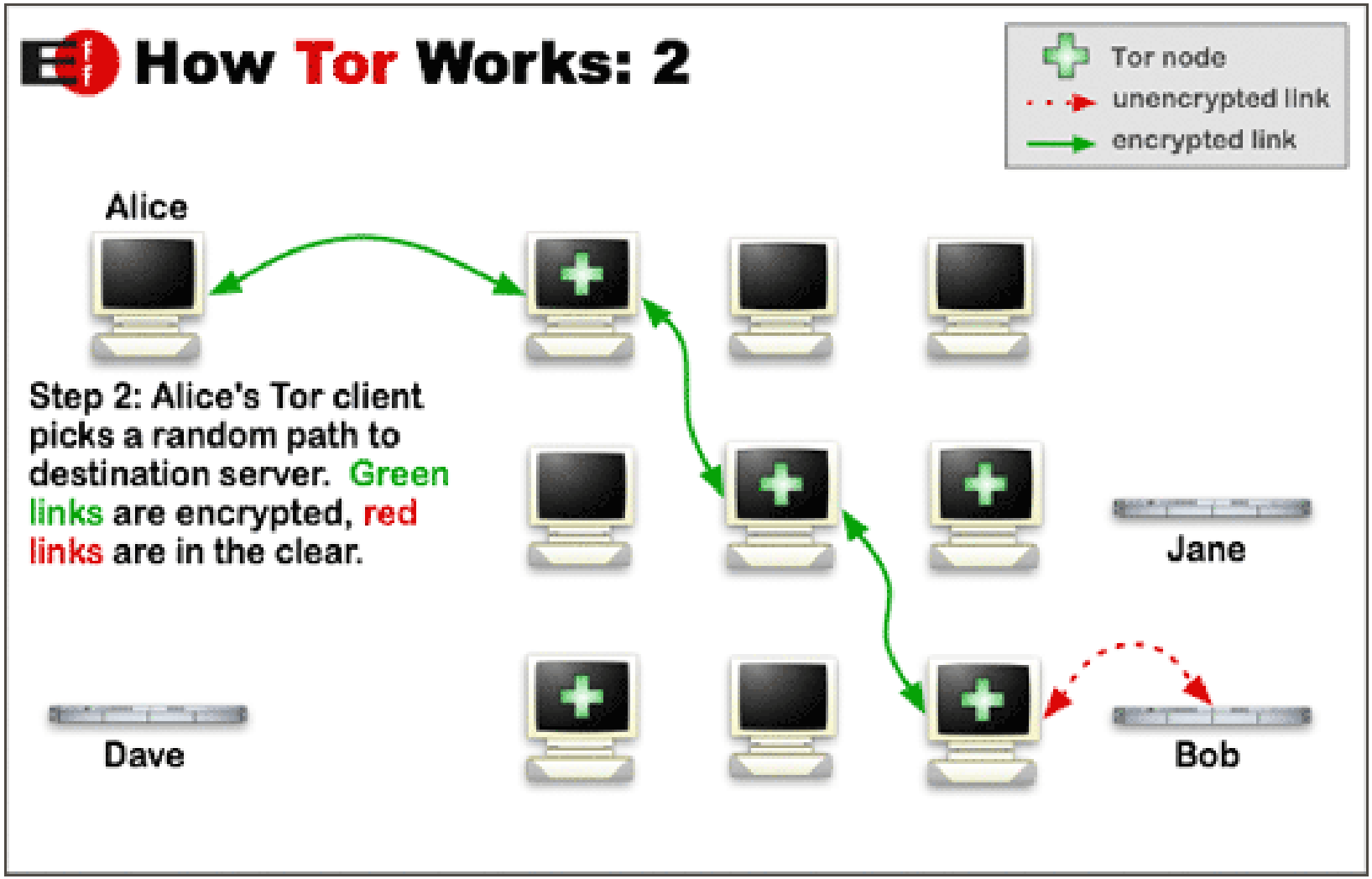

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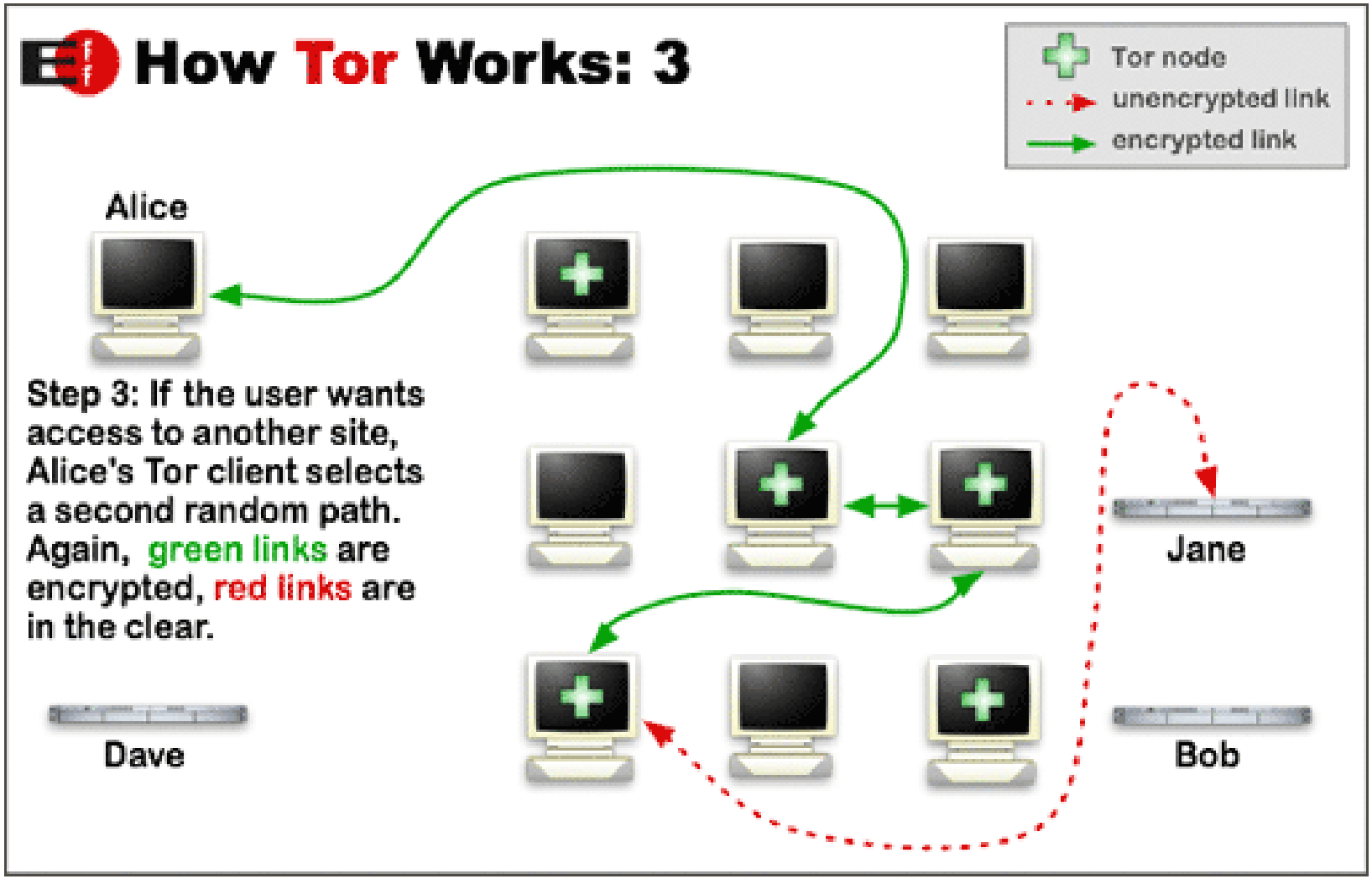
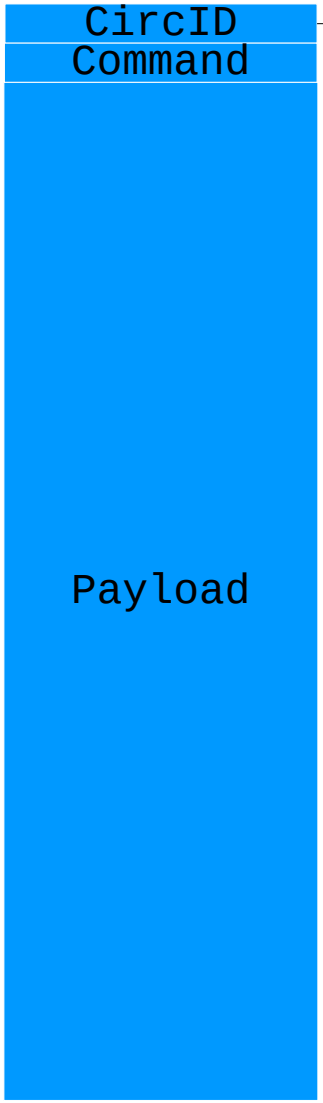
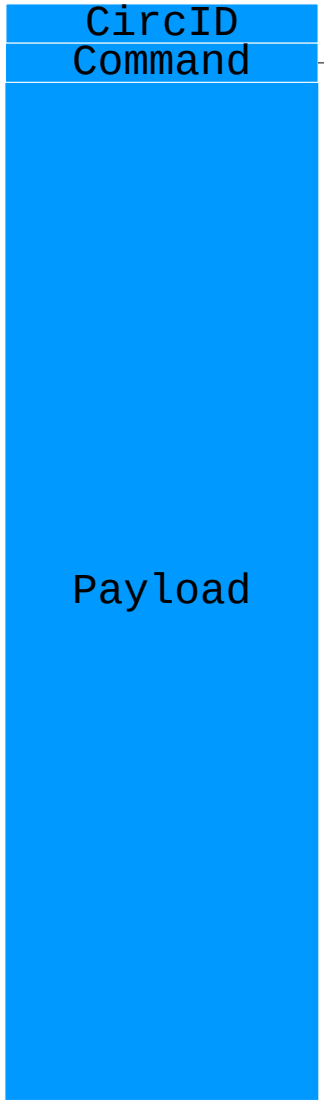


How Tor *in depth* works: Cells



Indicate which virtual circuit is associated the cell.
In fact we can create a different circuit for each connection we establish.
In reality, is better to MULTIPLEX more communication in one circuit.

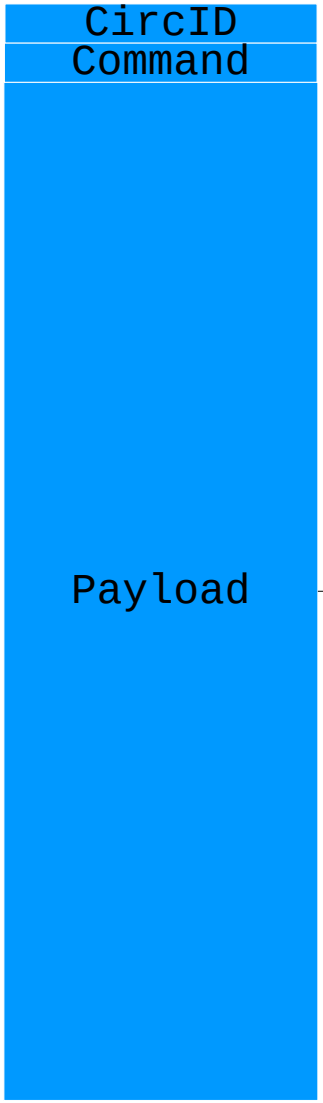
How Tor *in depth* works: Cells



It Holds the value of one of the command supported by the protocol. It can assume this values:

```
0 – PADDING          (Padding)
1 – CREATE           (Create a circuit)
2 – CREATED          (Acknowledge create)
3 – RELAY            (End-to-end data)
4 – DESTROY          (Stop using a circuit)
5 – CREATE_FAST      (Create a circuit,no PK)
6 – CREATED_FAST     (Circuit created,no PK)
7 – VERSIONS         (Negotiate versions)
8 – NETINFO          (Time and MITM-revention)
```

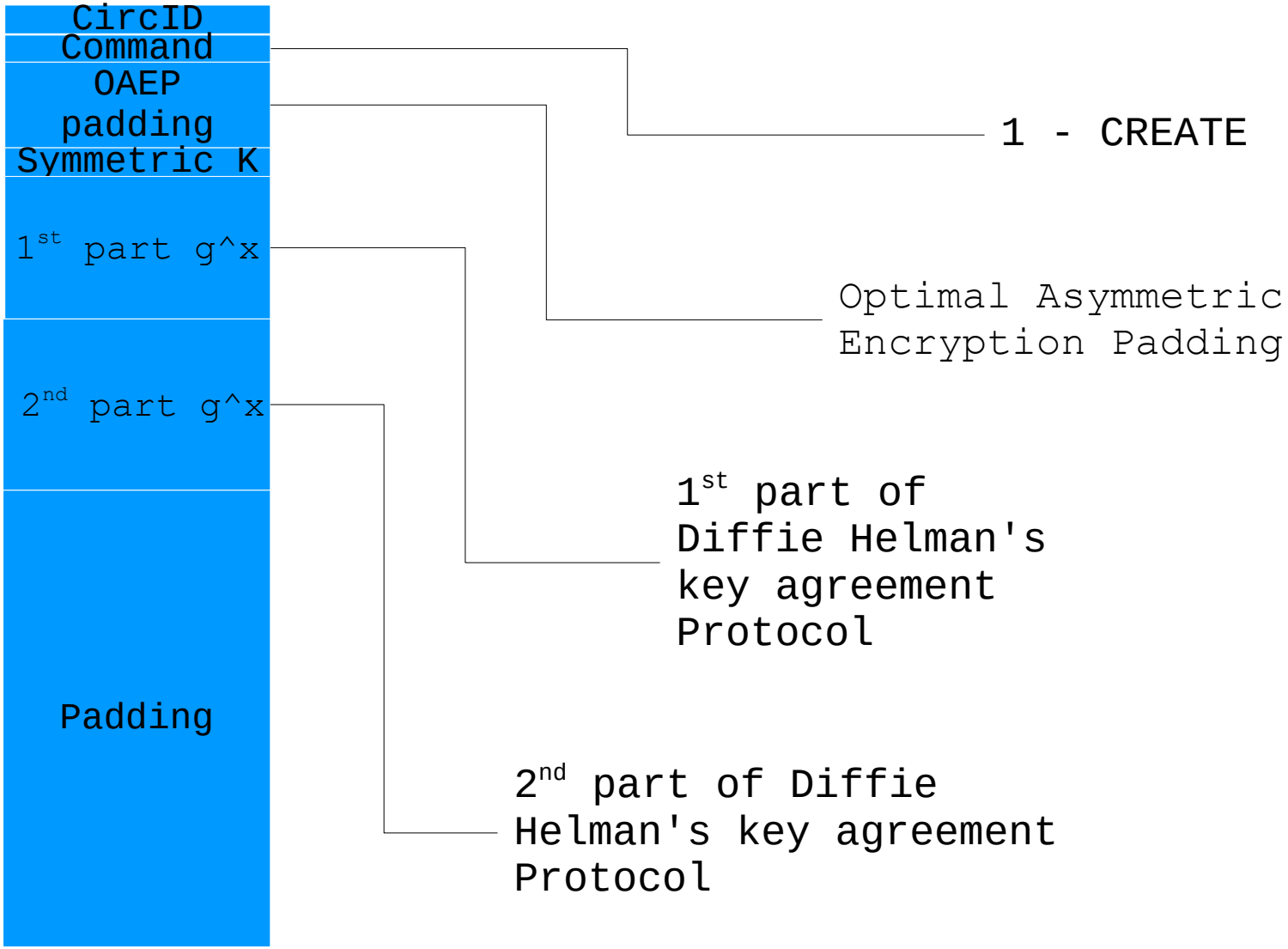
How Tor *in depth* works: Cells



Contains the data we want to transmit to another node. The interpretation of 'Payload' depends on the type of the cell.

```
PADDING:  Payload is unused.
CREATE:   Payload contains the handshake challenge.
CREATED:  Payload contains the handshake response.
RELAY:    Payload contains the relay header and
relay body.
DESTROY:  Payload contains a reason for closing the
circuit.
```

How Tor *in depth* works: Cells - Create



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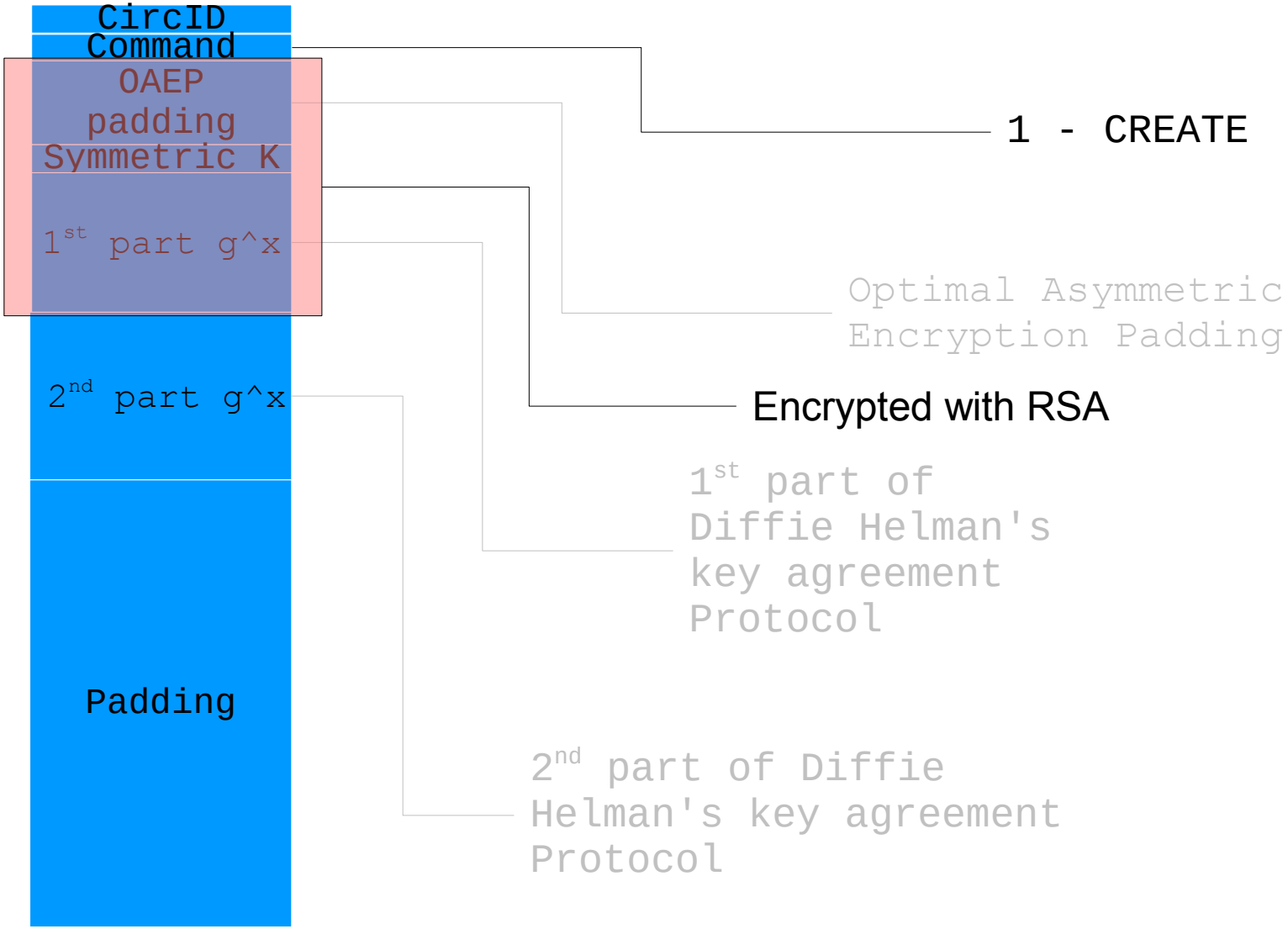

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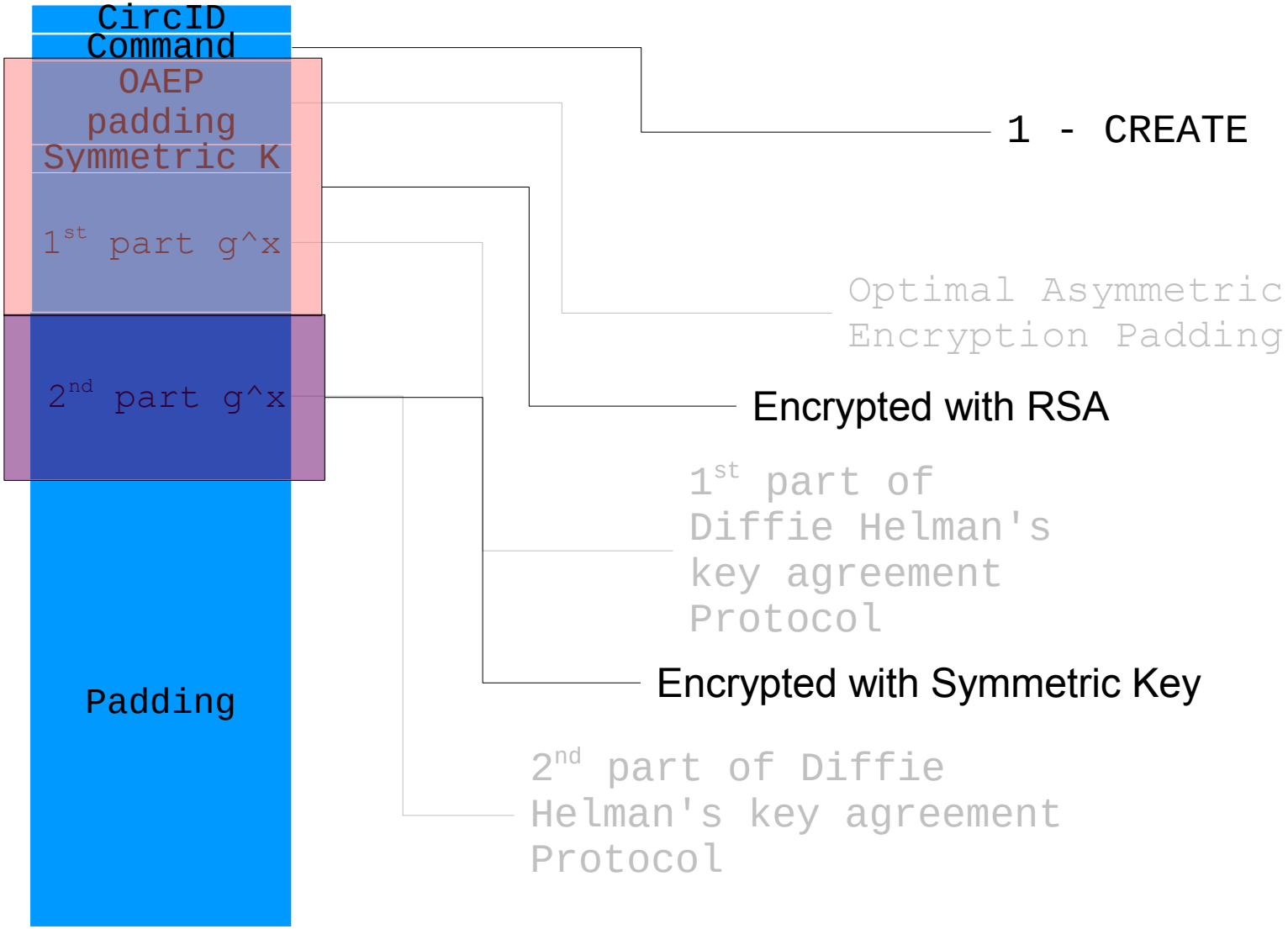

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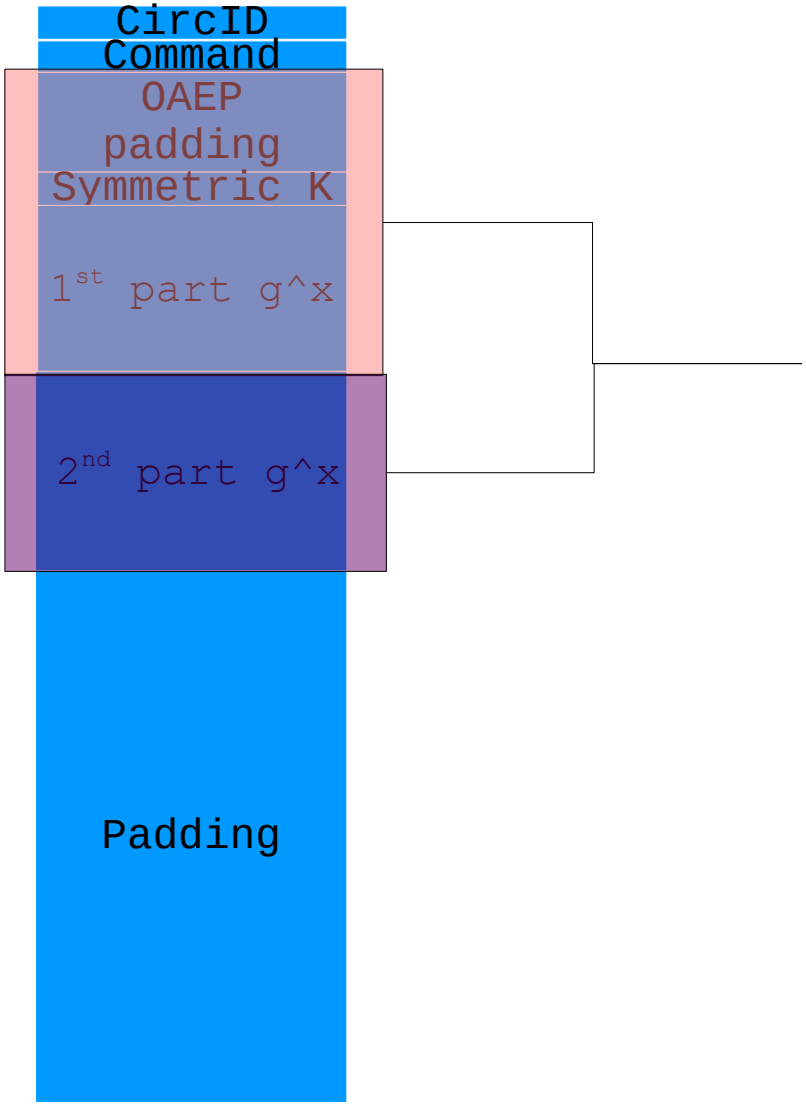
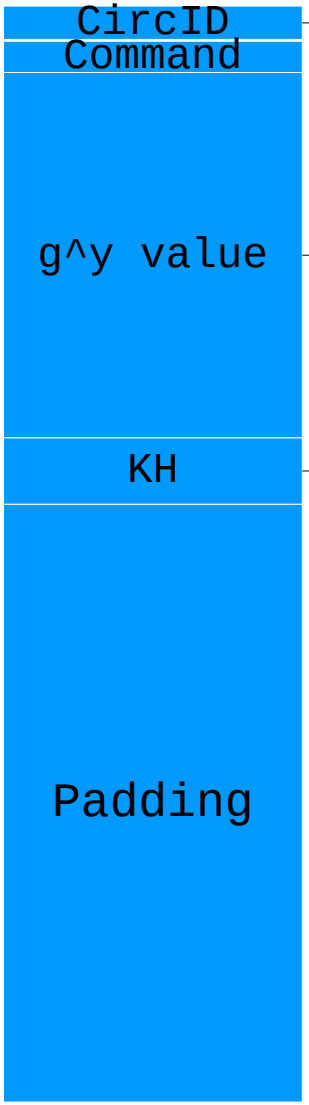


We make this choice for efficiency reason. Infact, this hybrid model make use of asymmetric crypto to grant a secure exchange for the key, that will be used to cyphe a big amount of data with better efficiency.

How Tor *in depth* works: Cells - Created

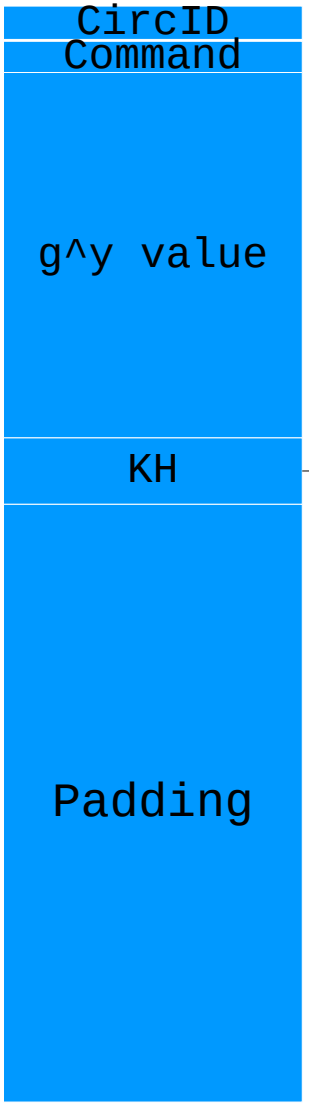


2 - CREATED

2nd part of DH protocol

Hash (SHA1) of the DH Key.
Demonstrate the knowledge of the entire DH Key

How Tor *in depth* works: Cells – Created – Derivative Key



- The g^xy computed value is used to derive K of 100 bytes according to the follow scheme:

```
K = H(g^xy | [00] | H(g^xy | [01]) | ... H(g^xy | [04])
```

- where | is the concatenation of its operand, **[NN]** is a byte which value is NN and **H(x)** is the SHA1 hash of x.

- From K will be consequently derived further value like derivative key ***(KH)***, forward digest ***(Df)***, backward digest ***(Db)***, forward key ***(Kf)*** and backward key ***(Kb)*** according the following schema: first 20 byte of K are *KH*, bytes 21-40 are *Df*, bytes 41-60 are *Db*, 61-76 are *Kf* e 77-92 are *Kb*.

How Tor *in depth* works: Cells – Relay

3 - RELAY

Can assume the following values:

1 -- RELAY_BEGIN
2 -- RELAY_DATA
3 -- RELAY_END
4 -- RELAY_CONNECTED
5 -- RELAY_SENDME
6 -- RELAY_EXTEND
7 -- RELAY_EXTENDED
8 -- RELAY_TRUNCATE
9 -- RELAY_TRUNCATED
10 -- RELAY_DROP
11 -- RELAY_RESOLVE
12 -- RELAY_RESOLVED

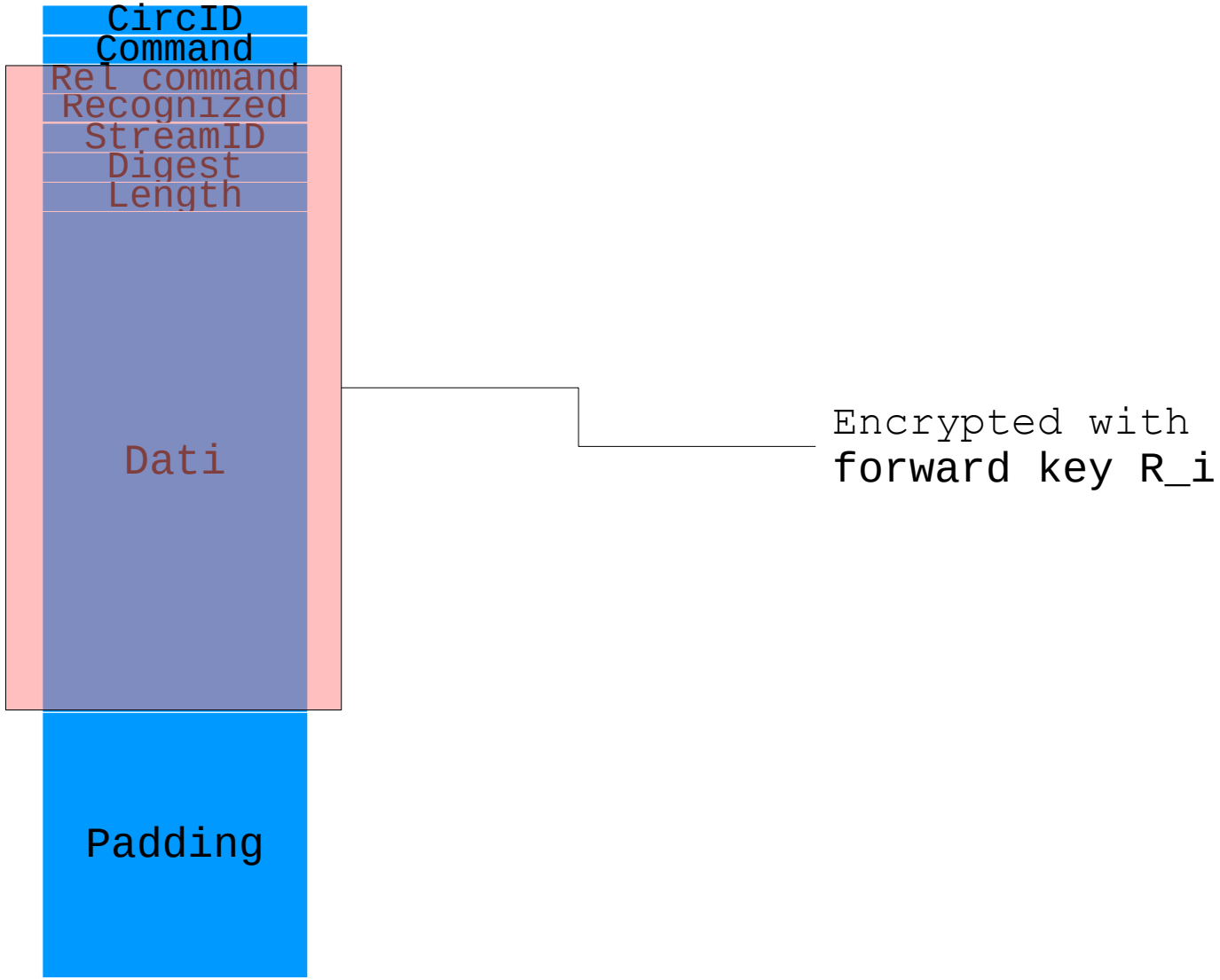
How Tor *in depth* works: Cells – Relay

3 - RELAY

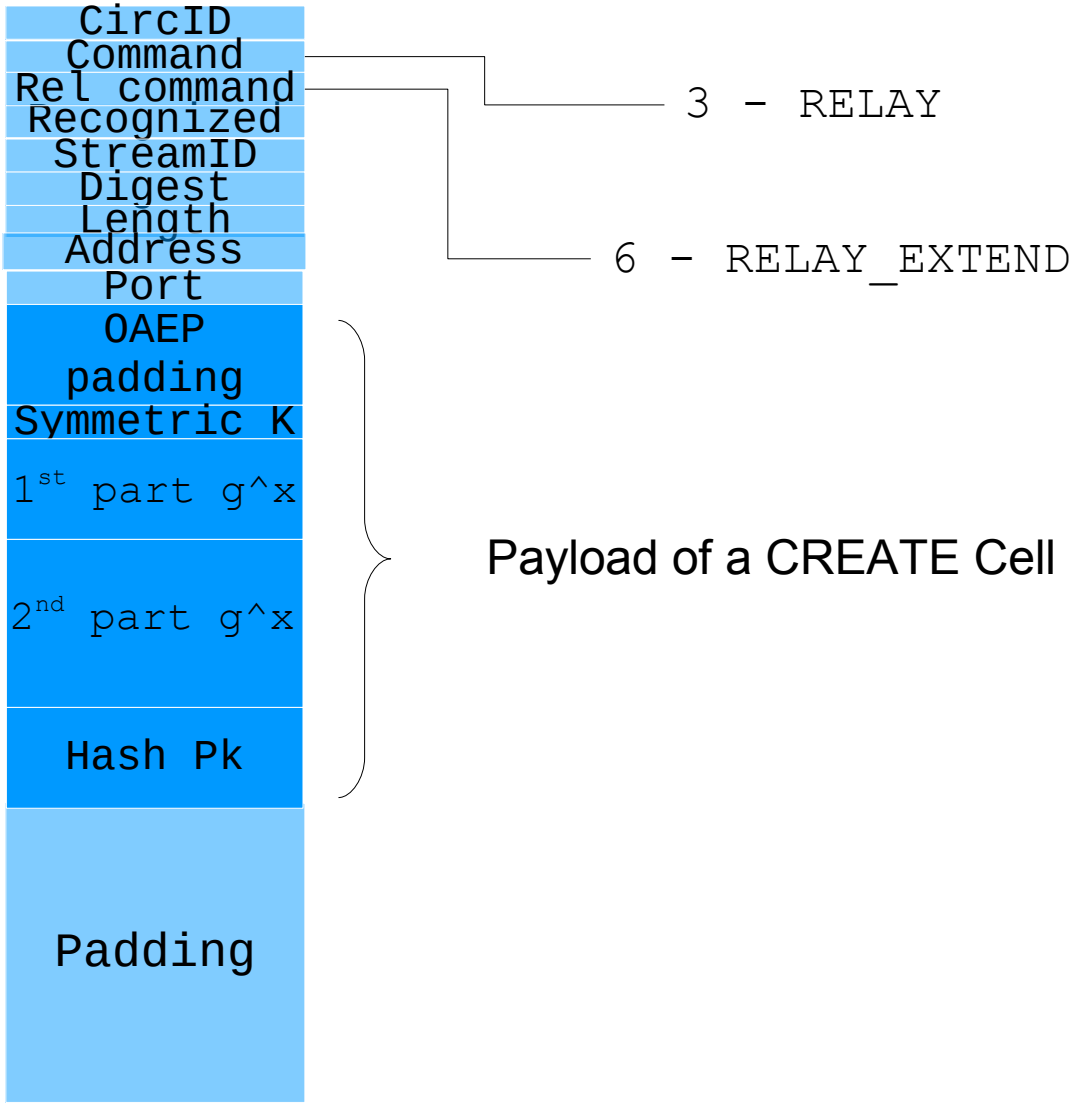
If this field is not equal to 0 the decrypted cell is routed to the next circuit's Onion Router, otherwise the payload content is processed by the same node.

Used to determine the cells that belongs to the same data stream.

How Tor *in depth* works: Cells – Relay



How Tor *in depth* works: Cells – Relay Extend



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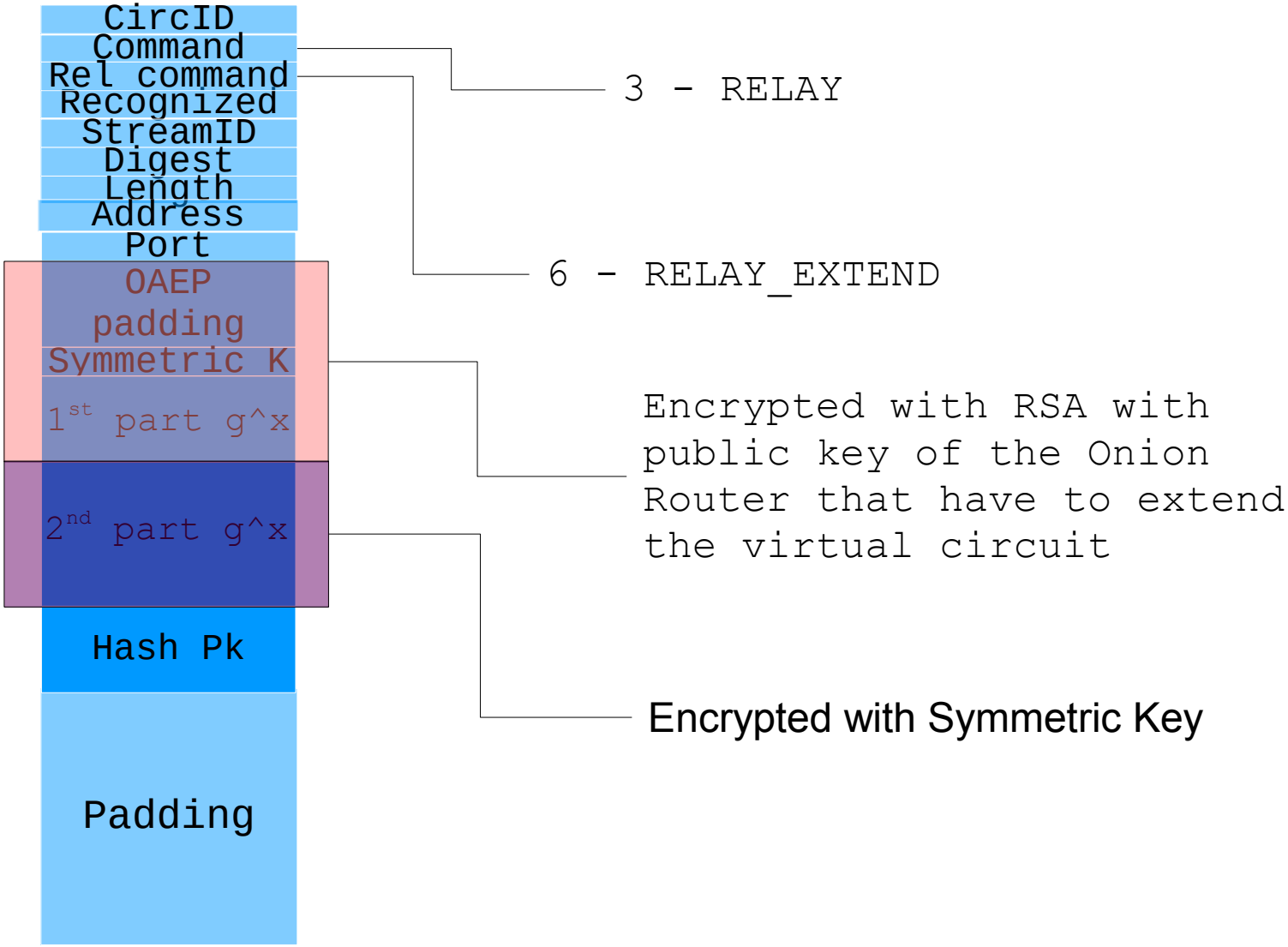
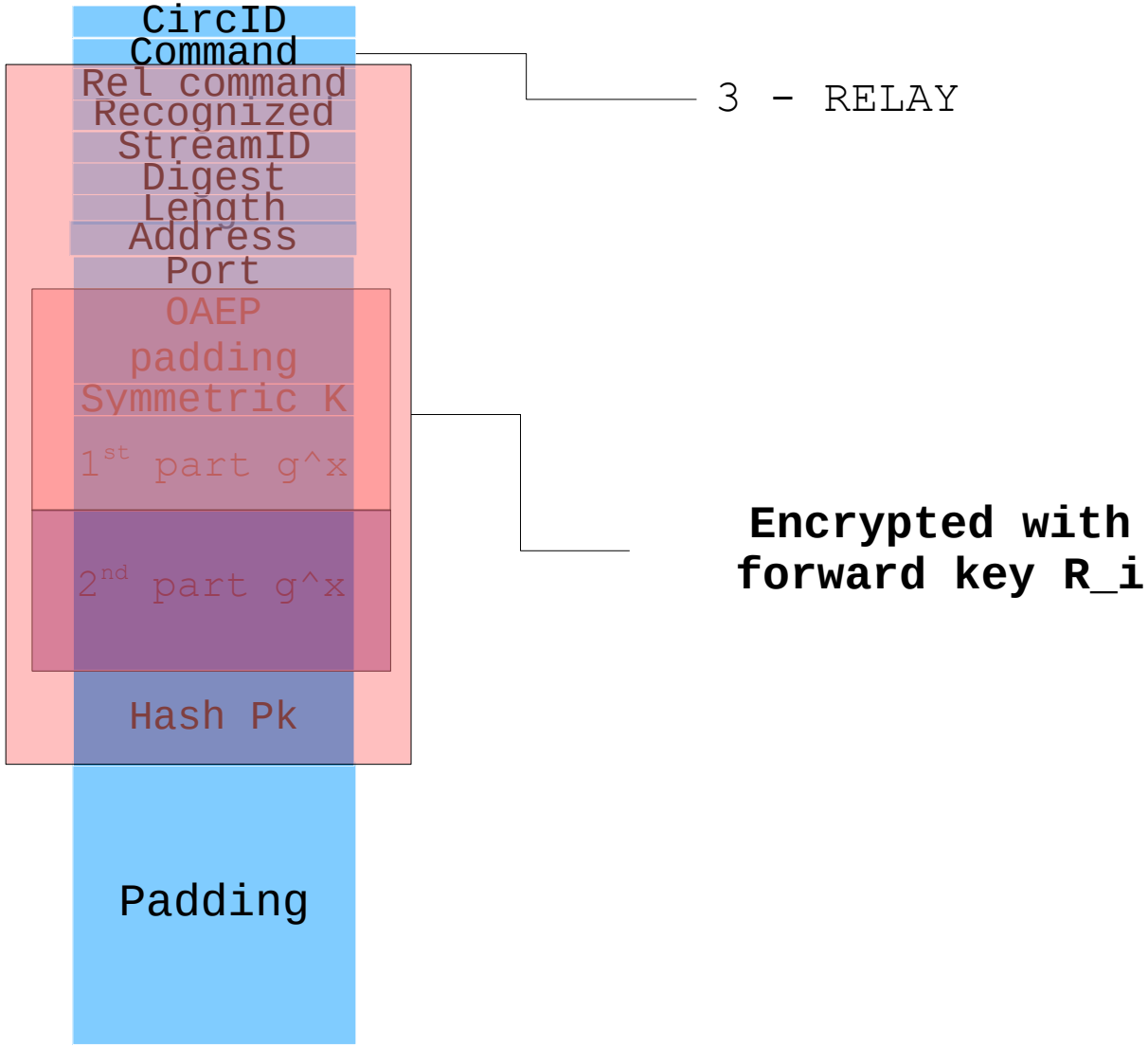


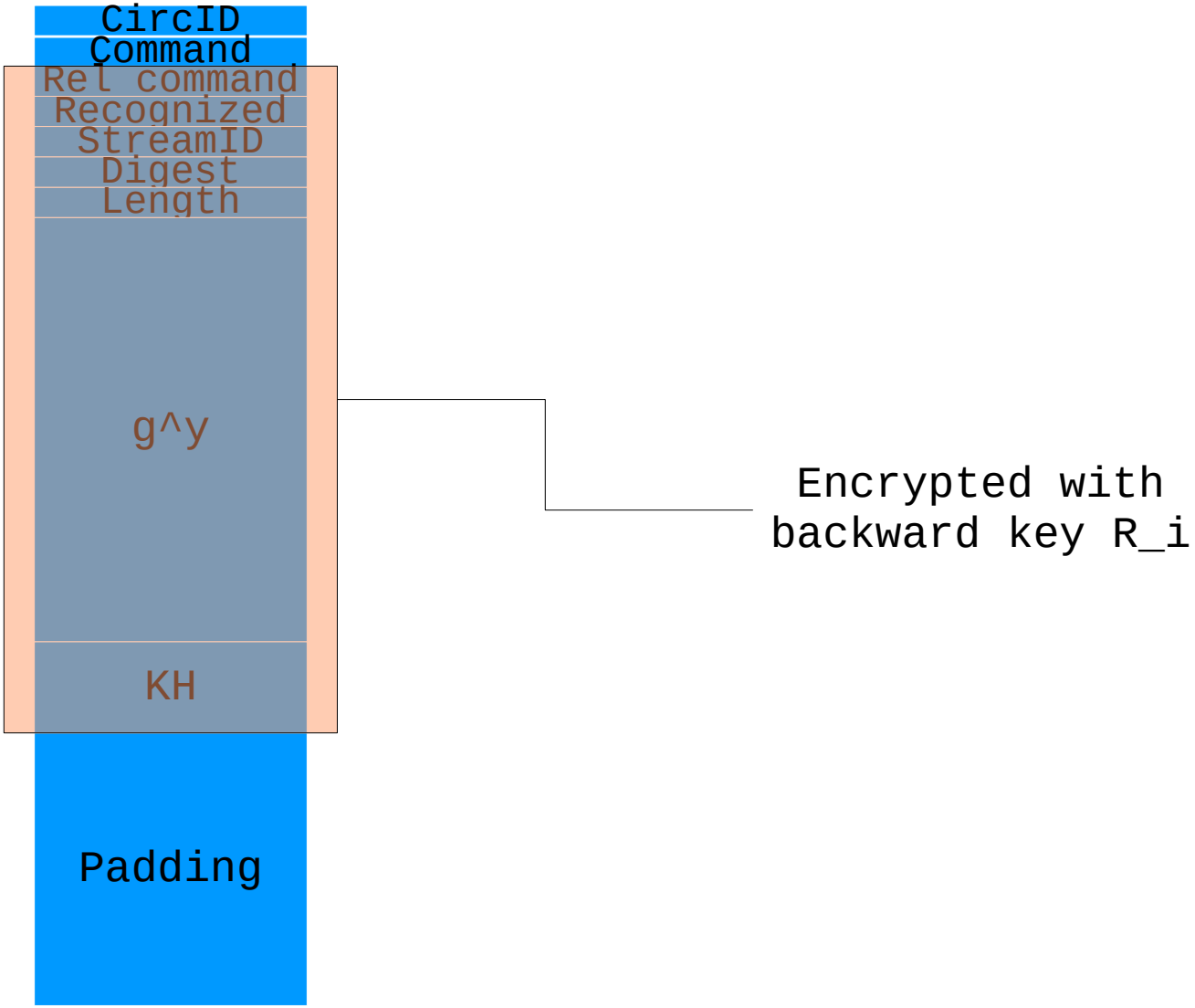
How Tor *in depth* works: Cells – Relay Extend



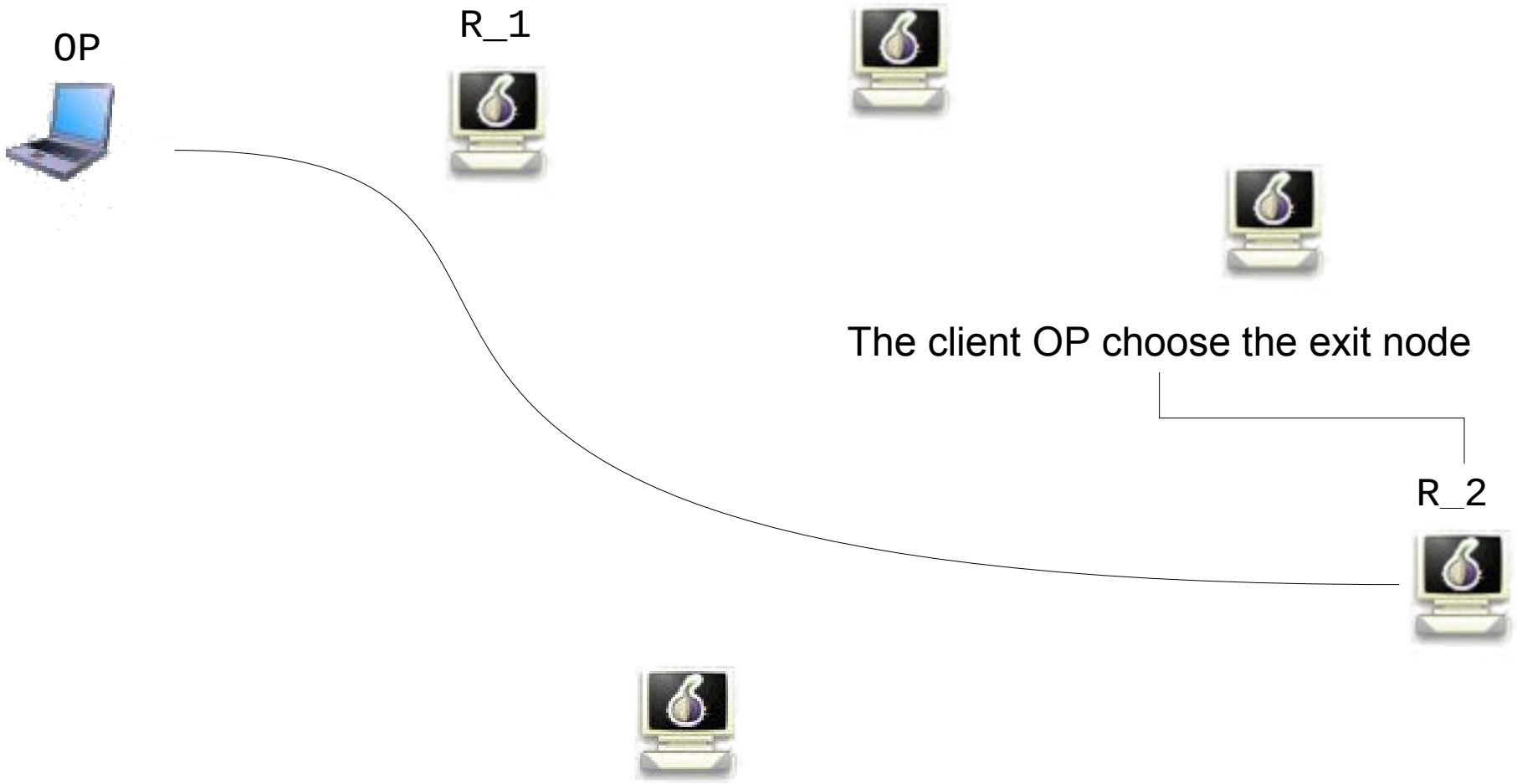
How Tor *in depth* works: Cells – Relay Extended

Payload of a CREATED Cell

How Tor *in depth* works: Cells – Relay Extended



How Tor *in depth* works: Circuit



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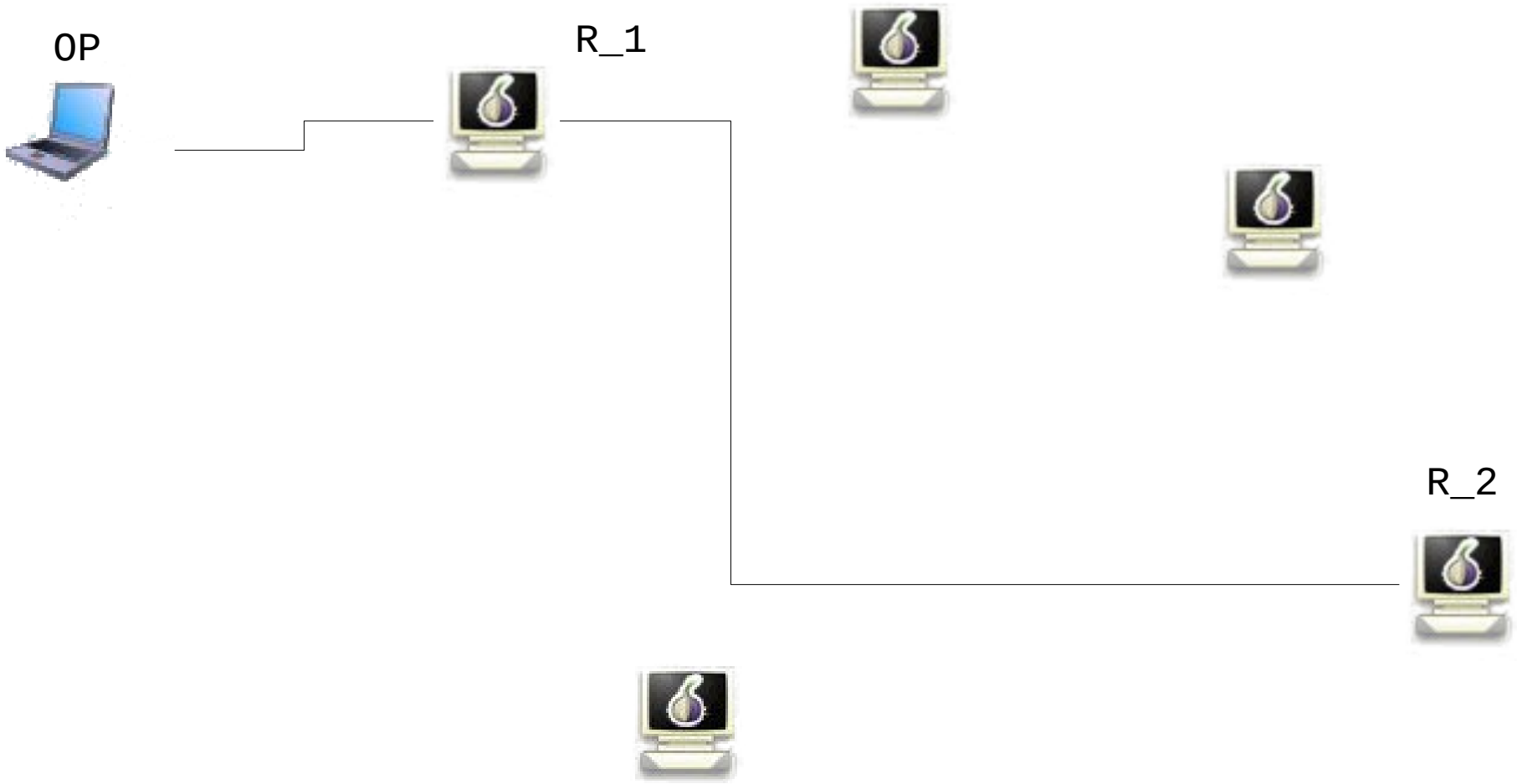

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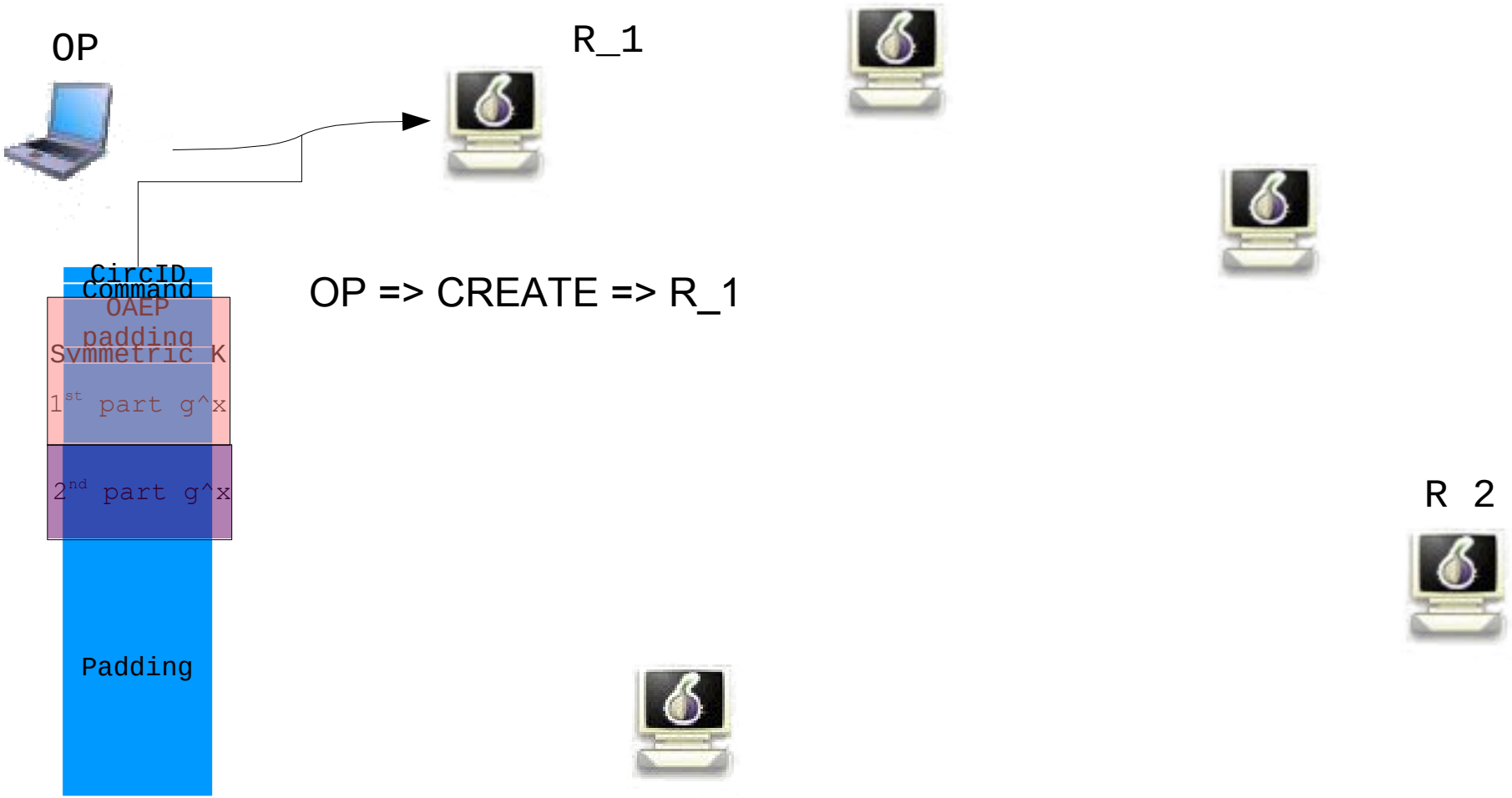

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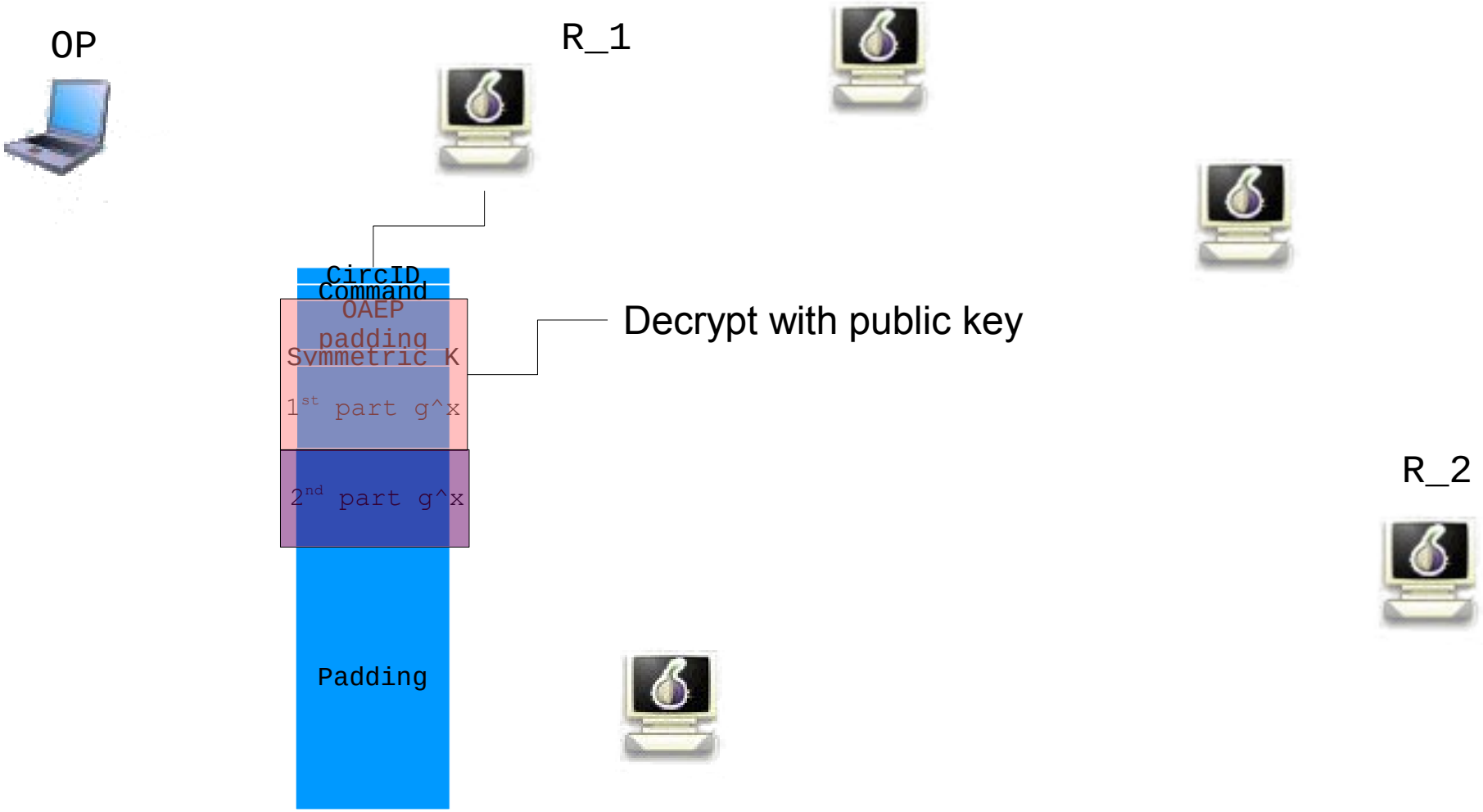

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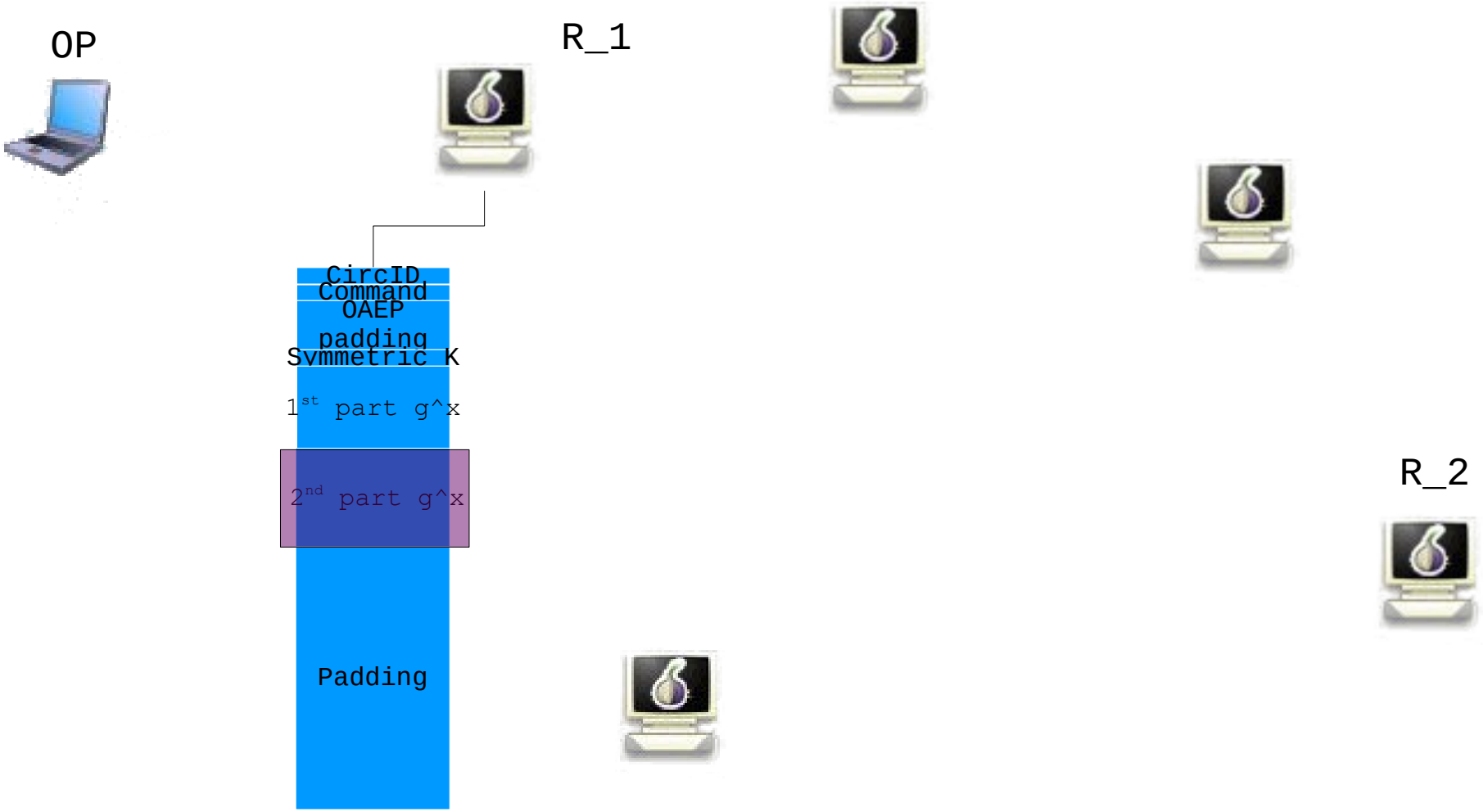

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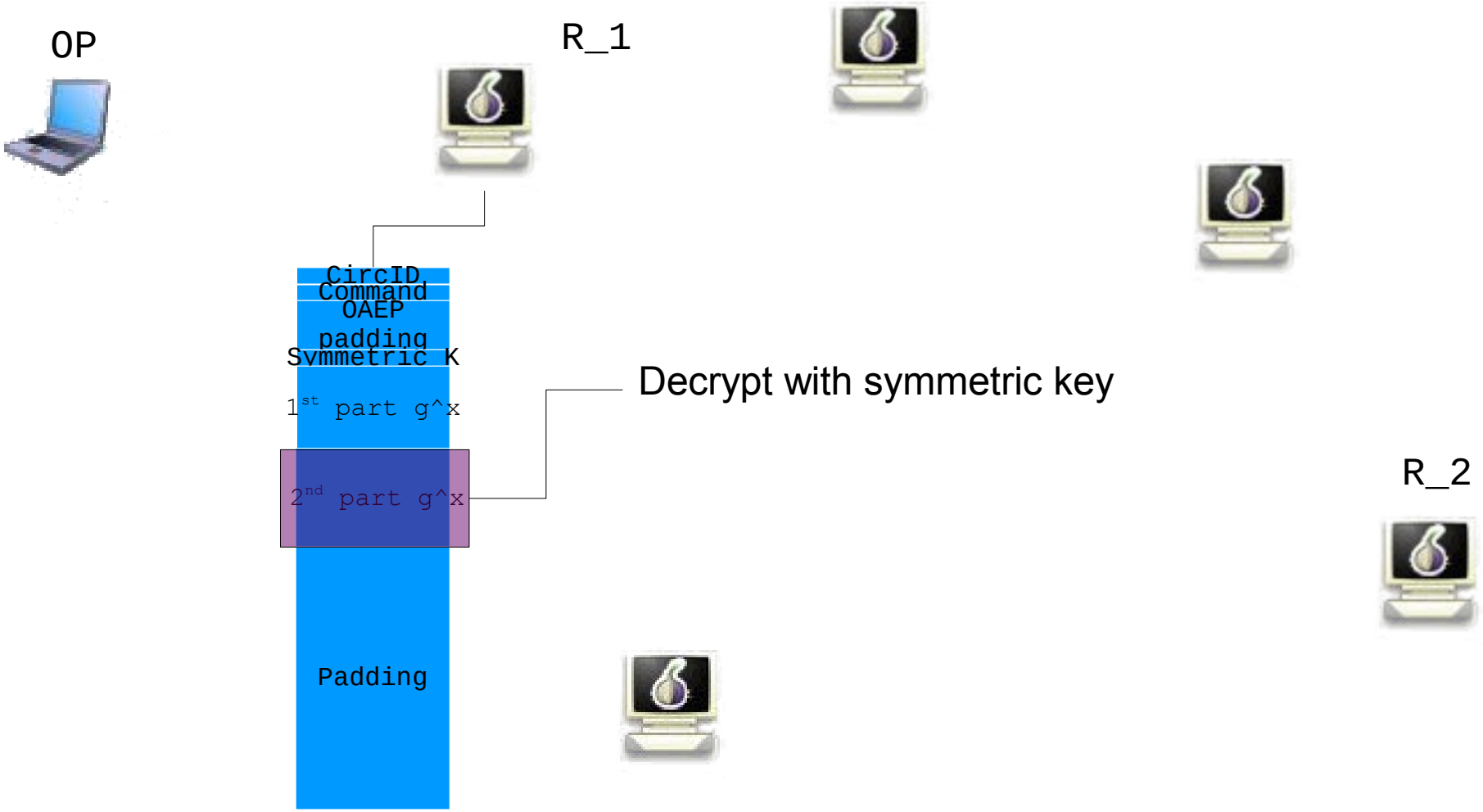
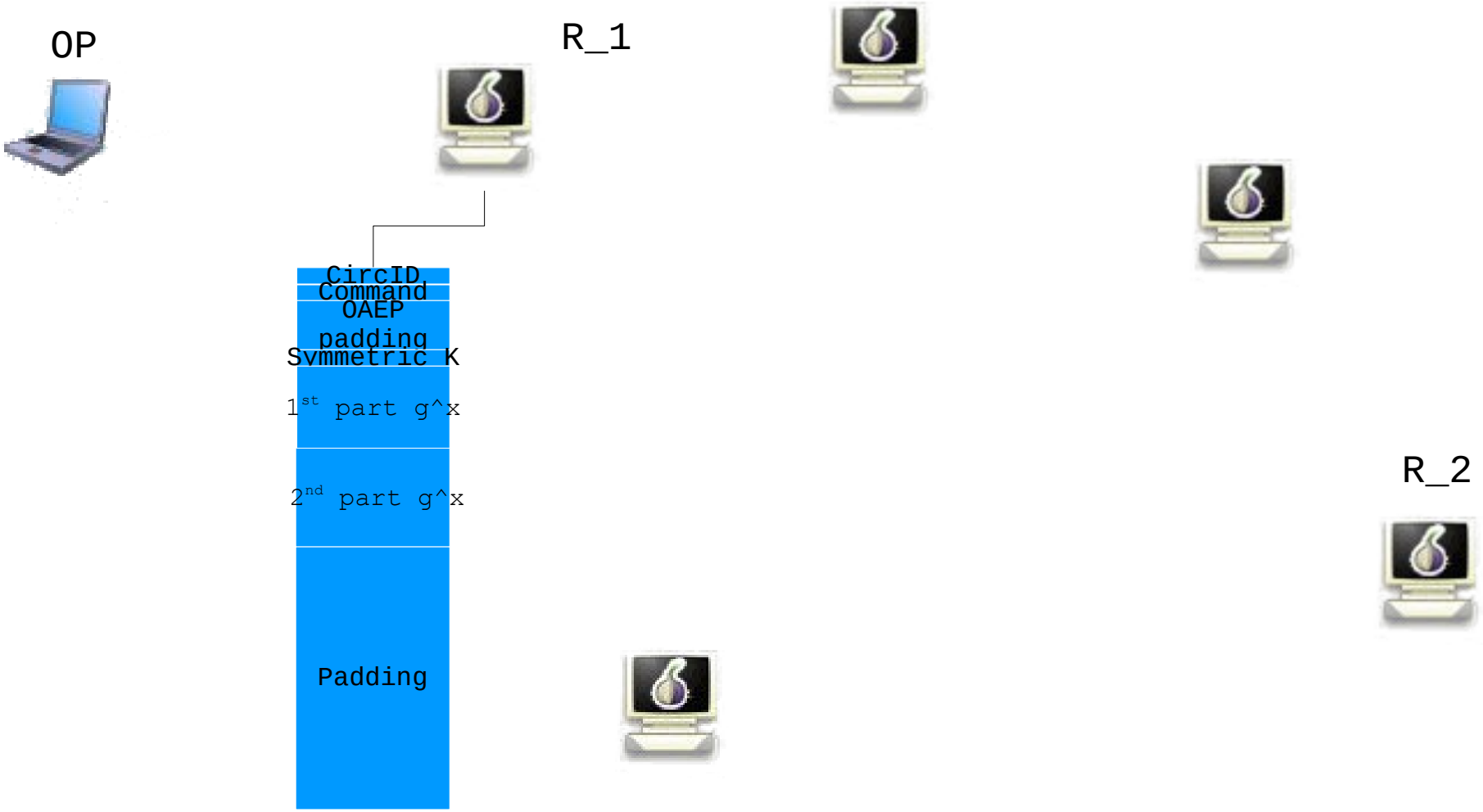


How Tor *in depth* works: Circuit



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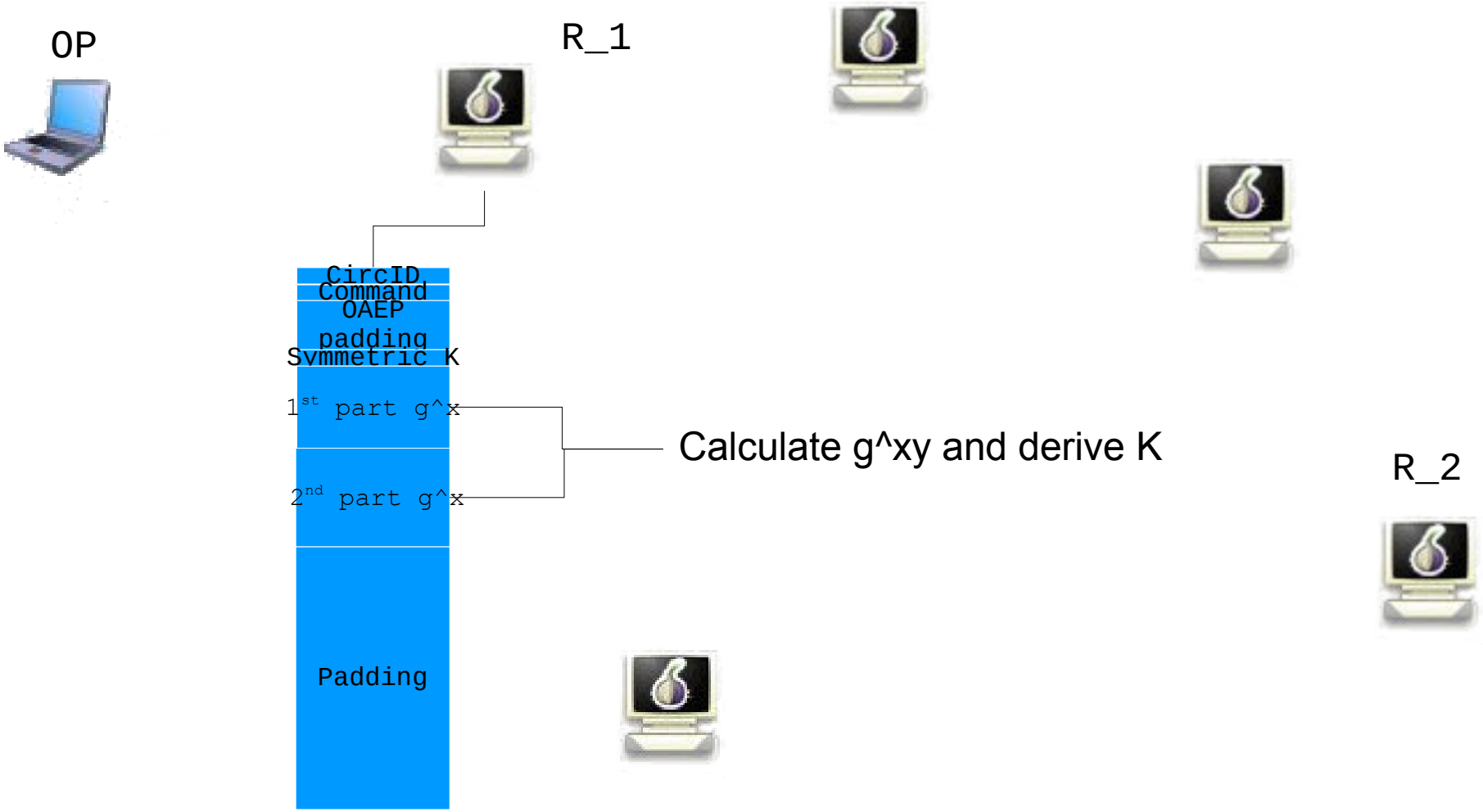

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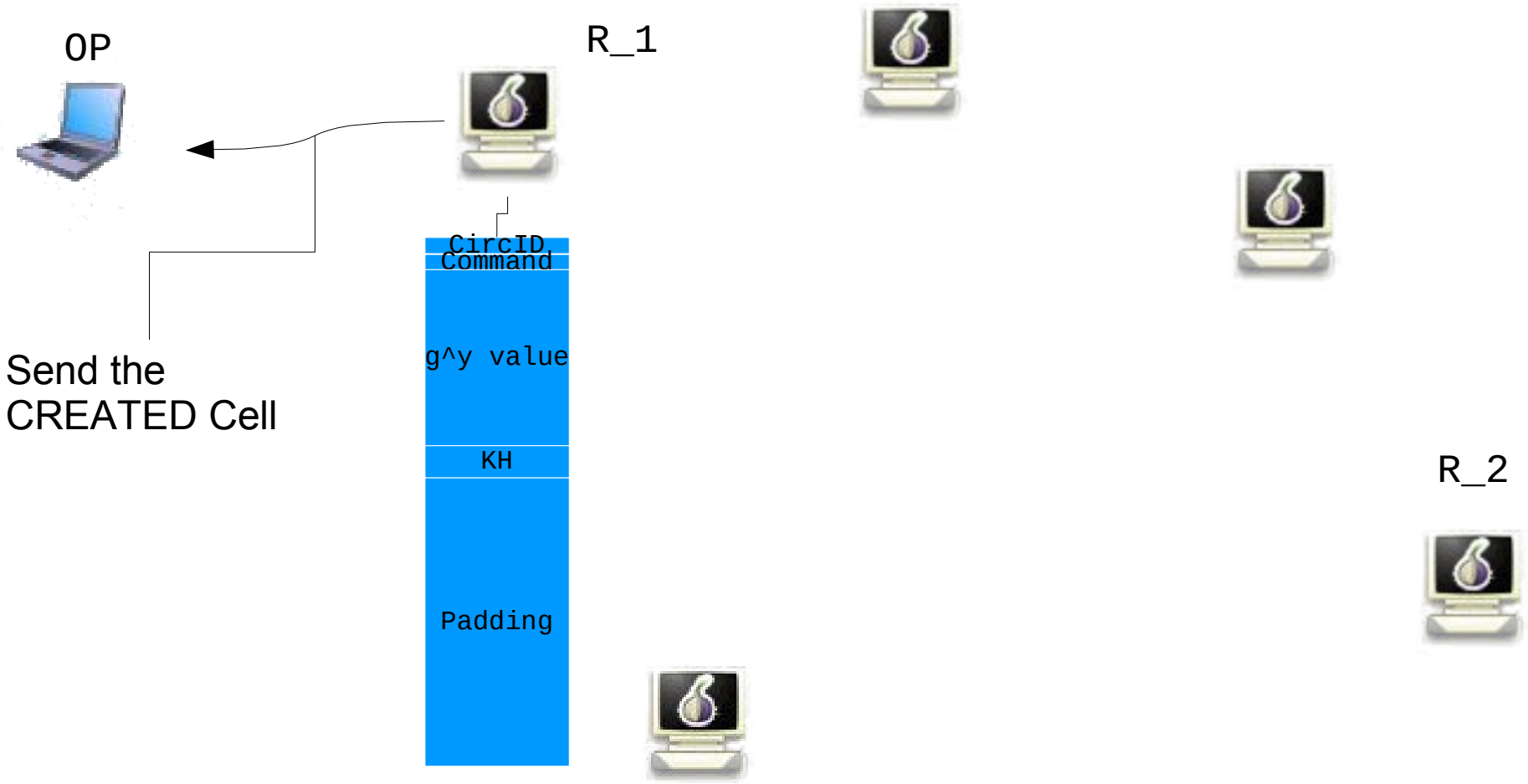

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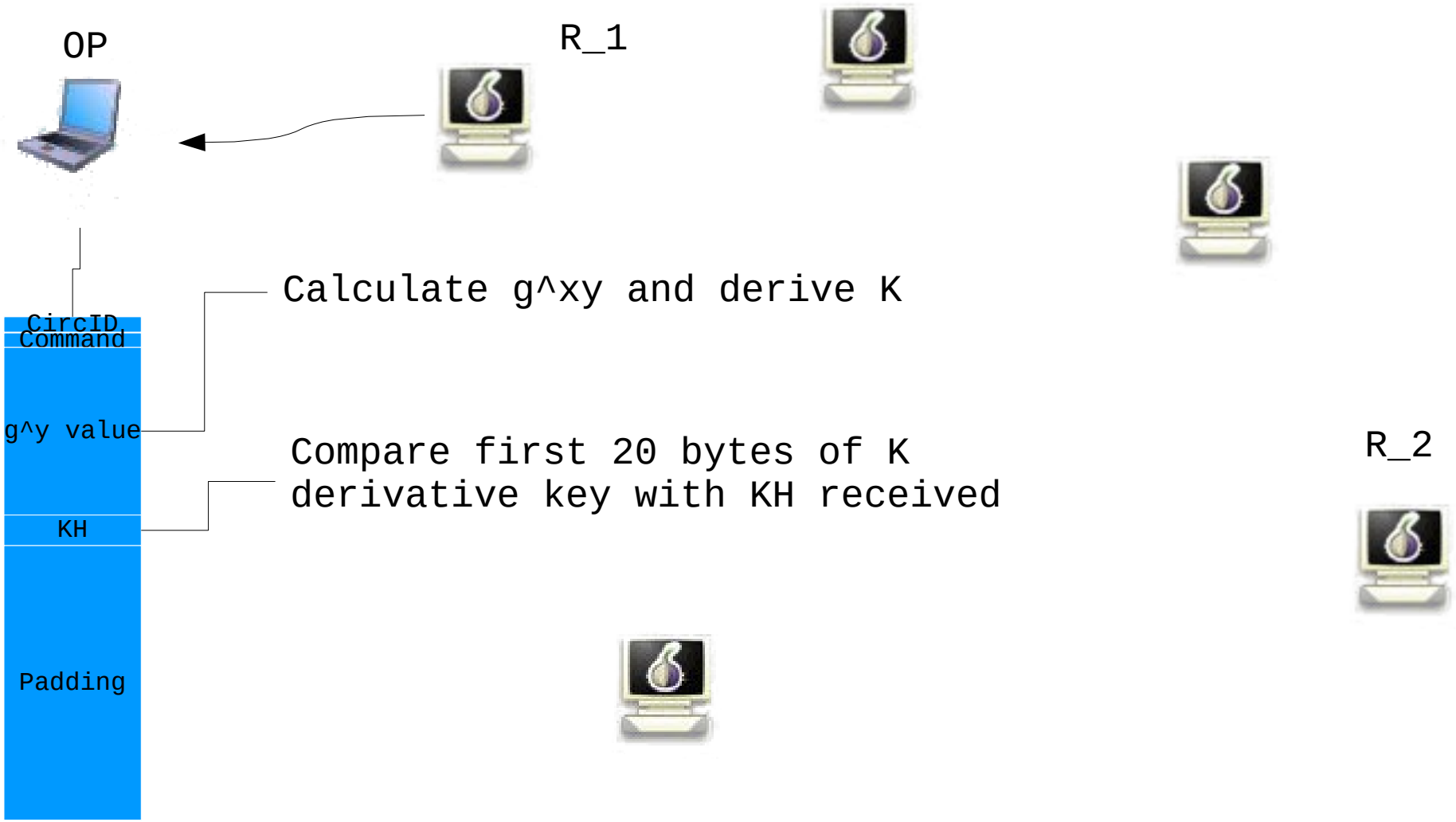

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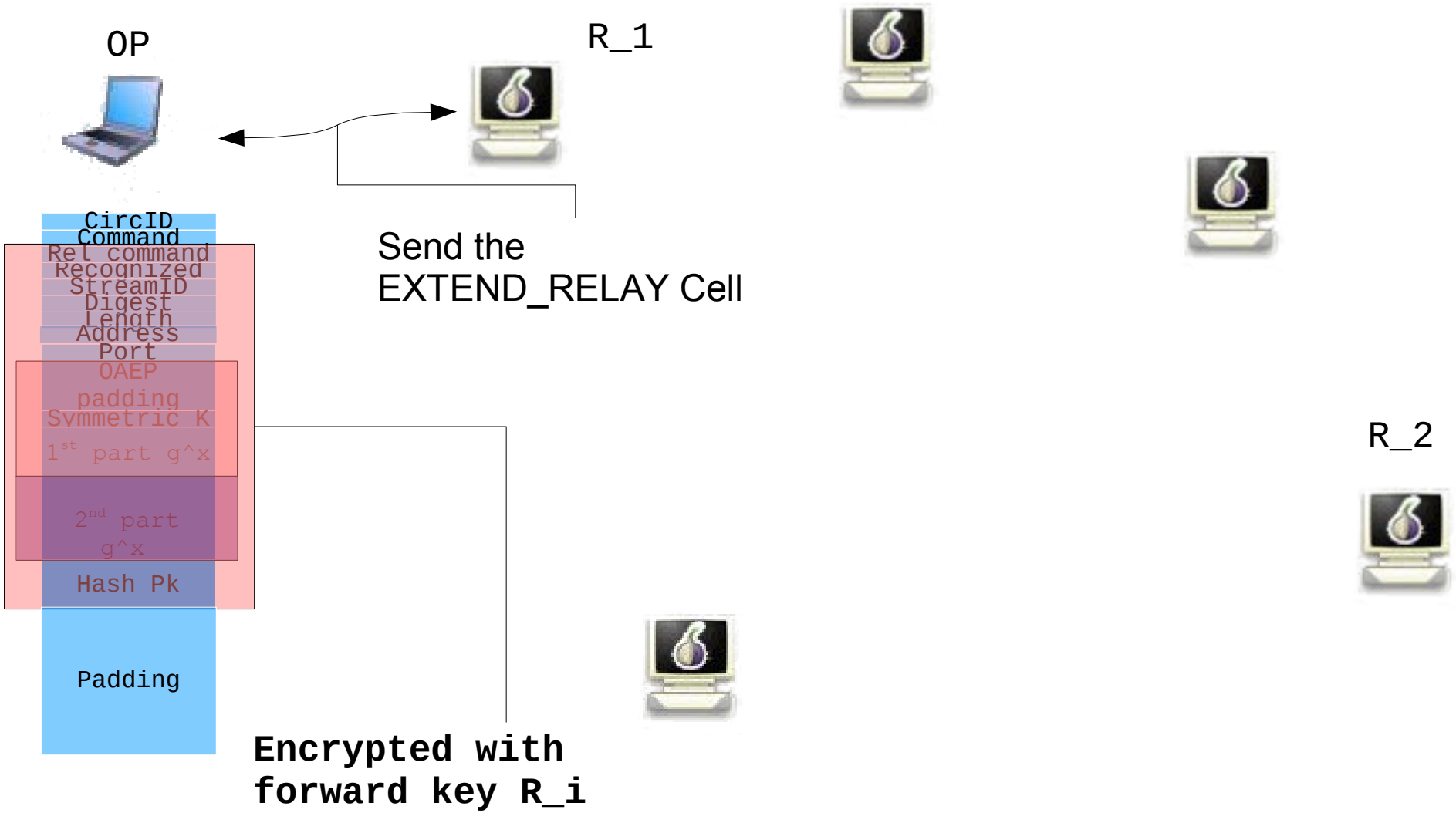
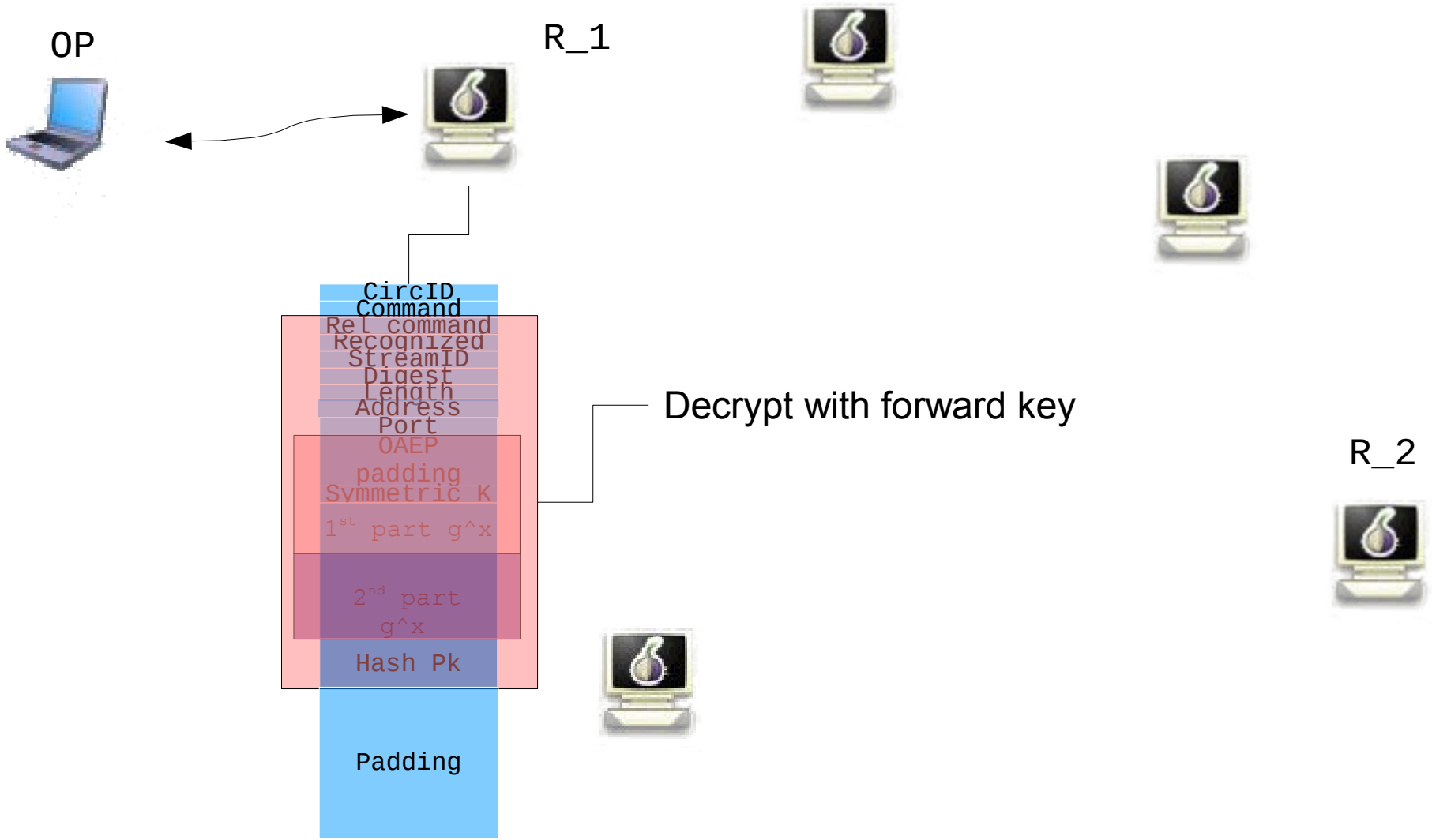


How Tor *in depth* works: Circuit



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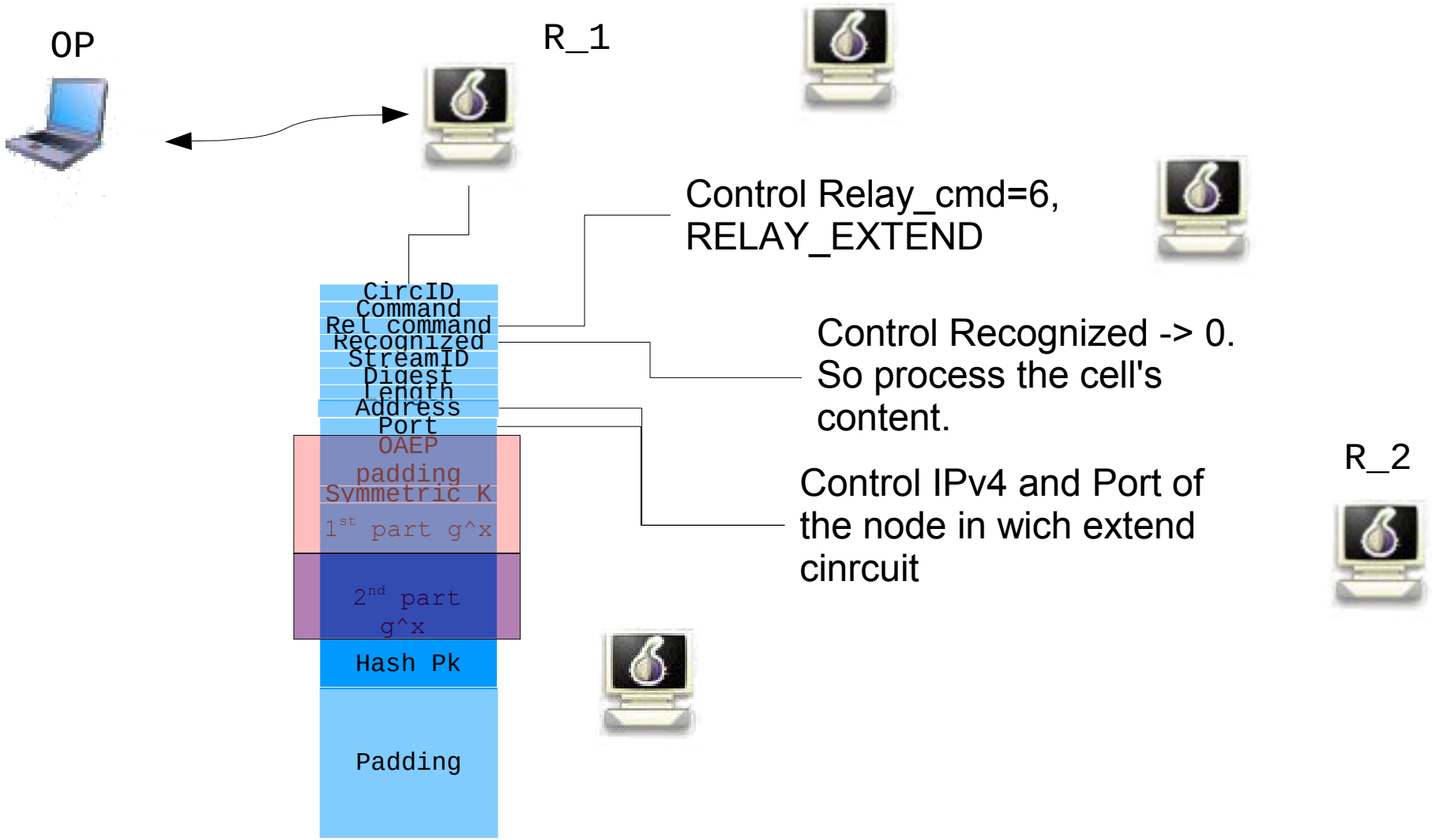

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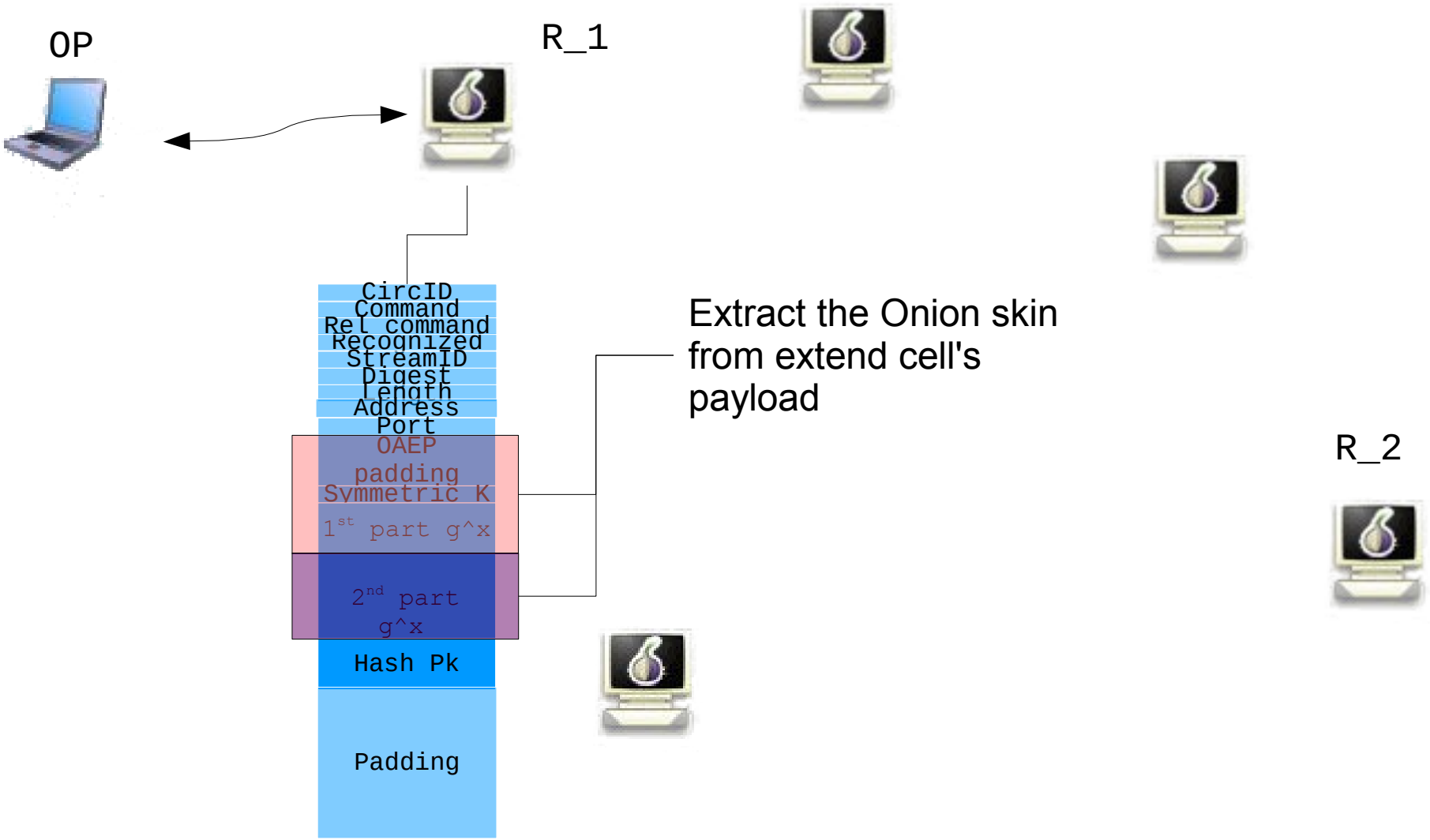
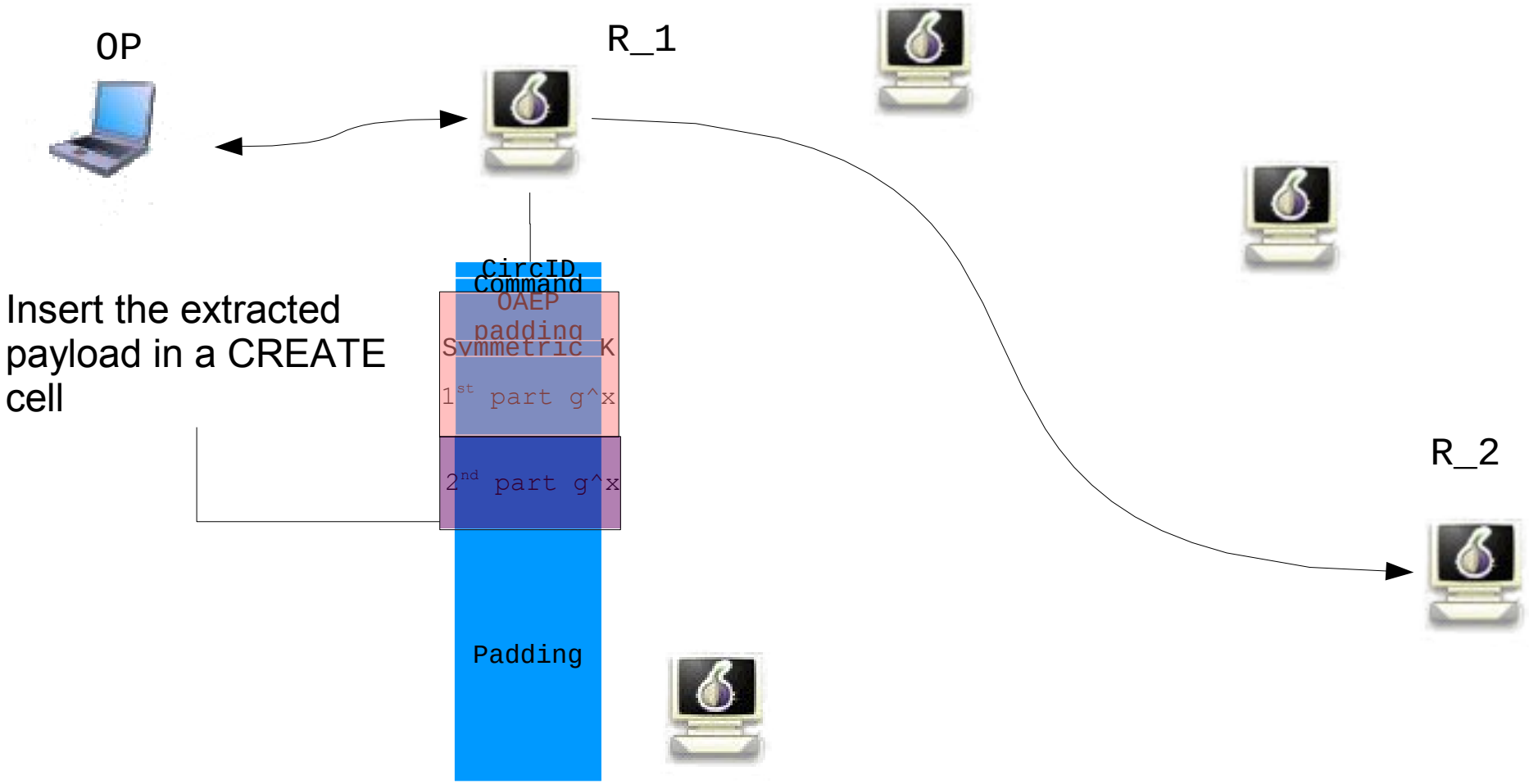


How Tor *in depth* works: Circuit



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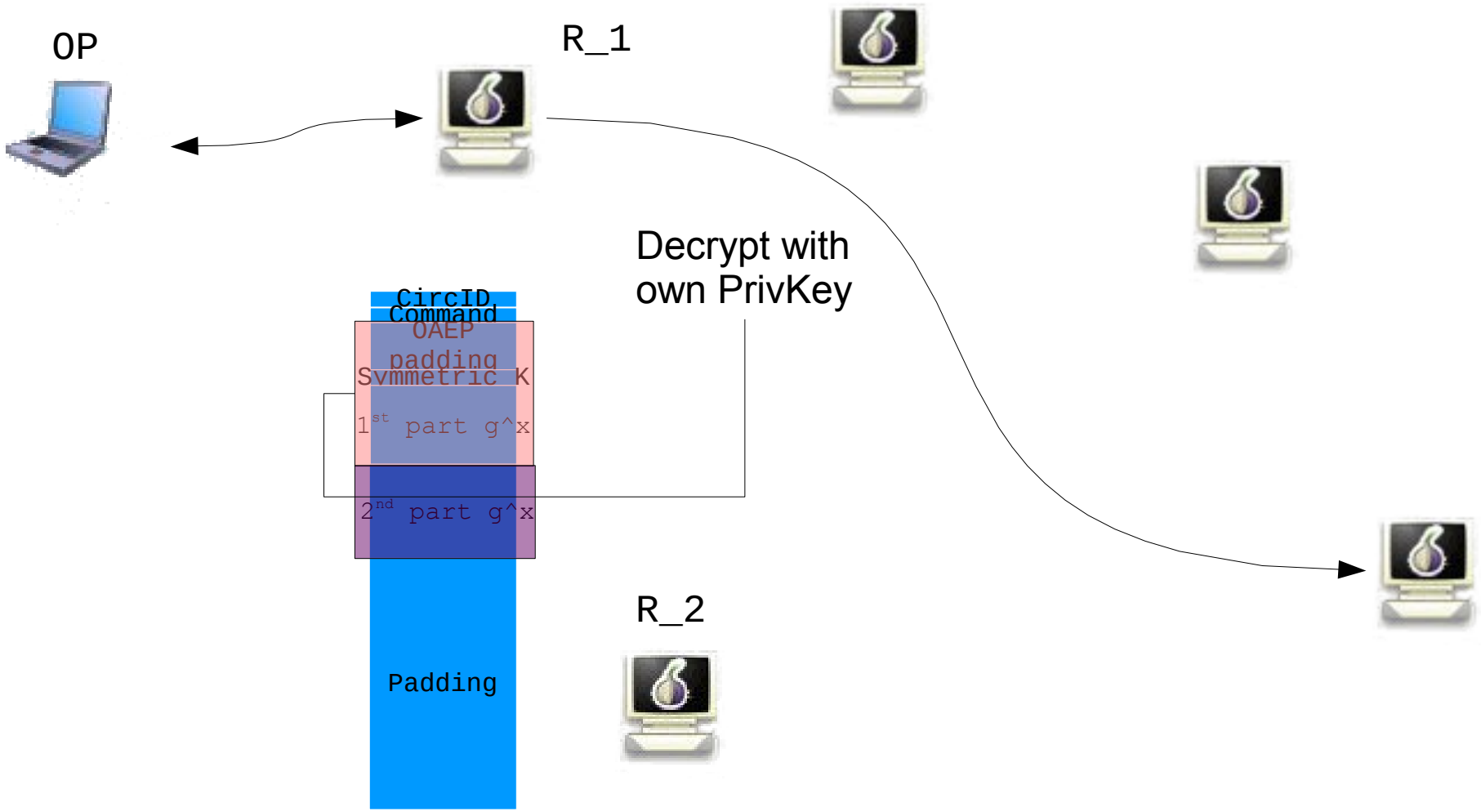

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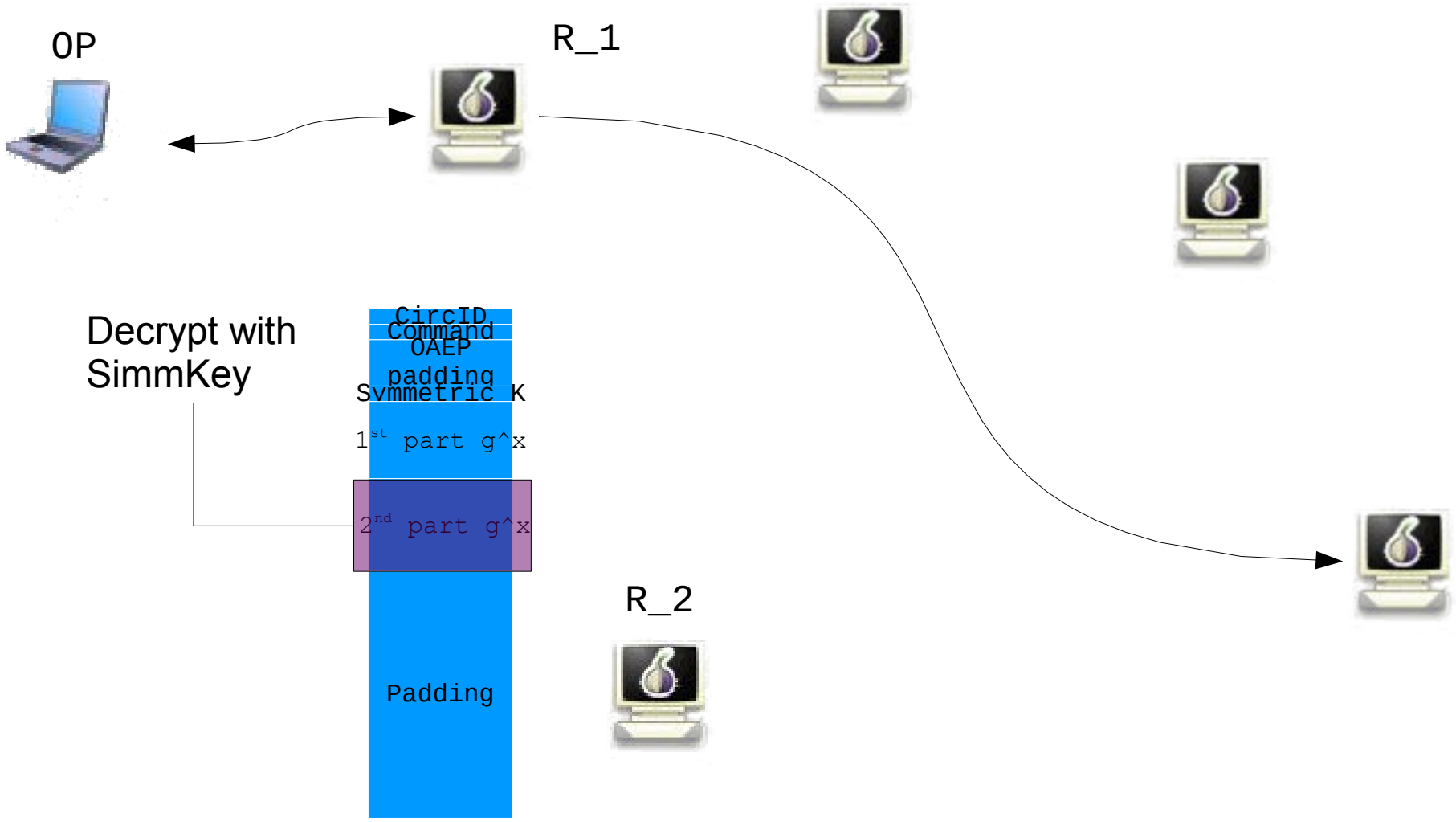

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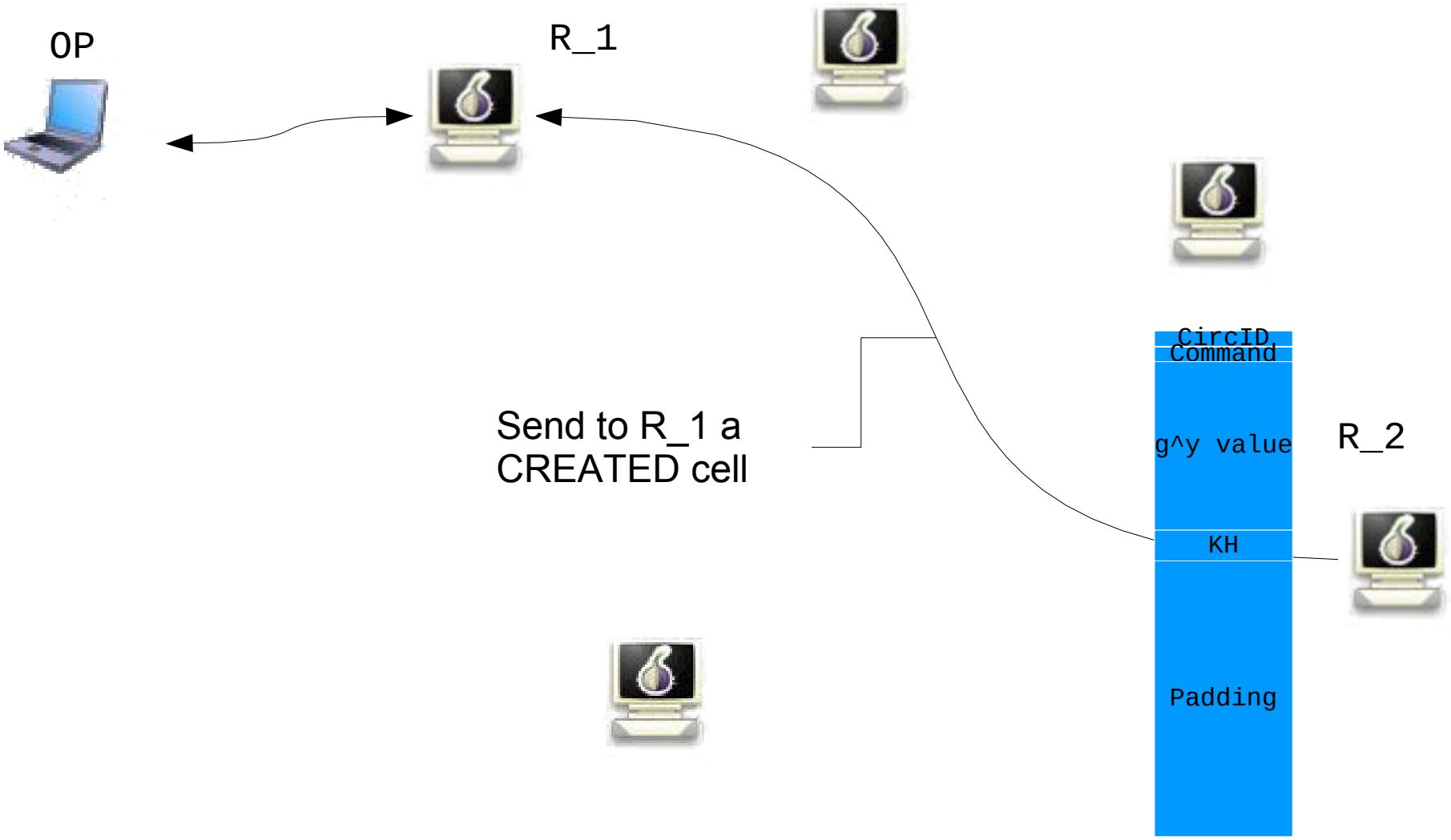
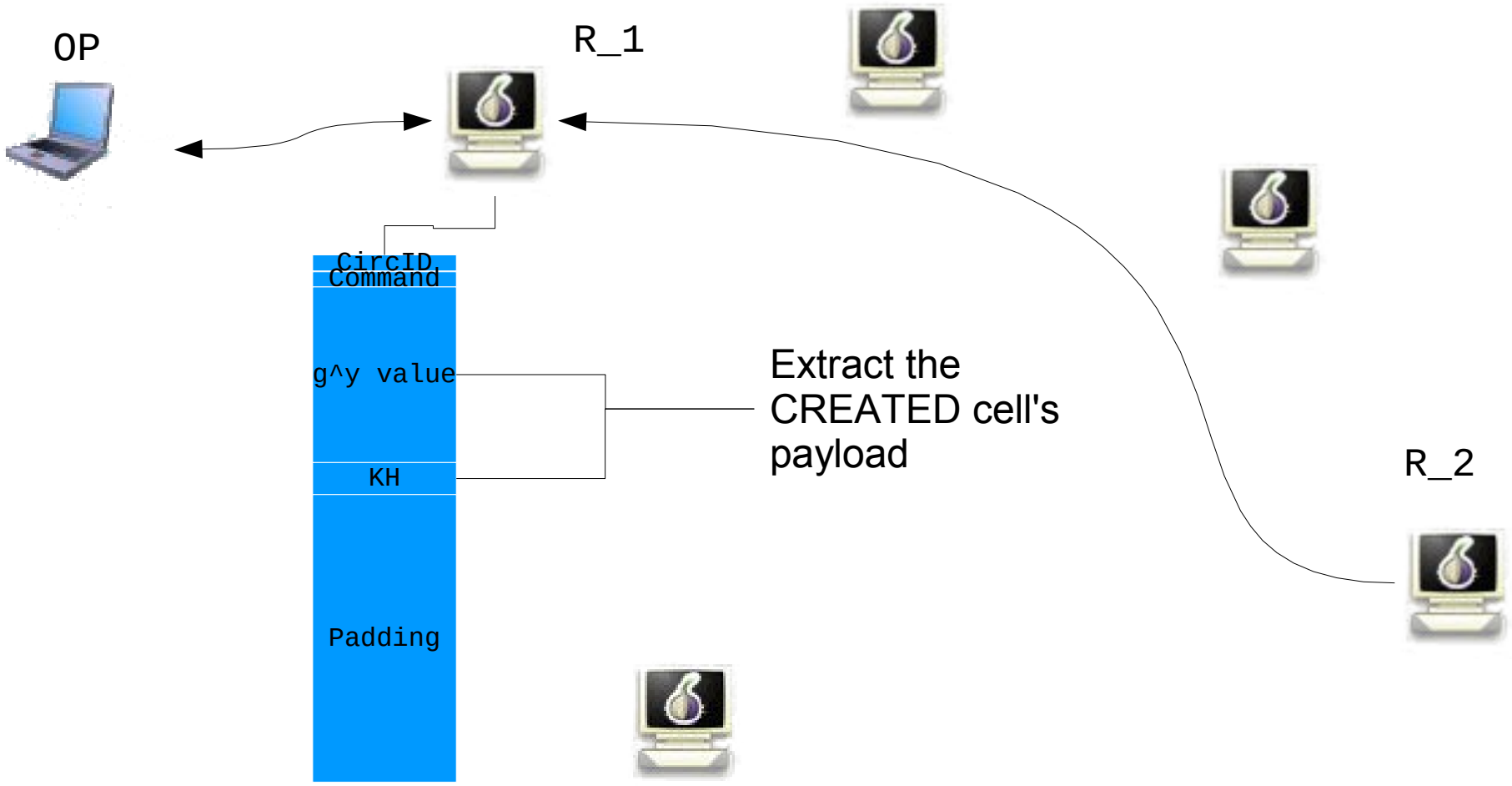
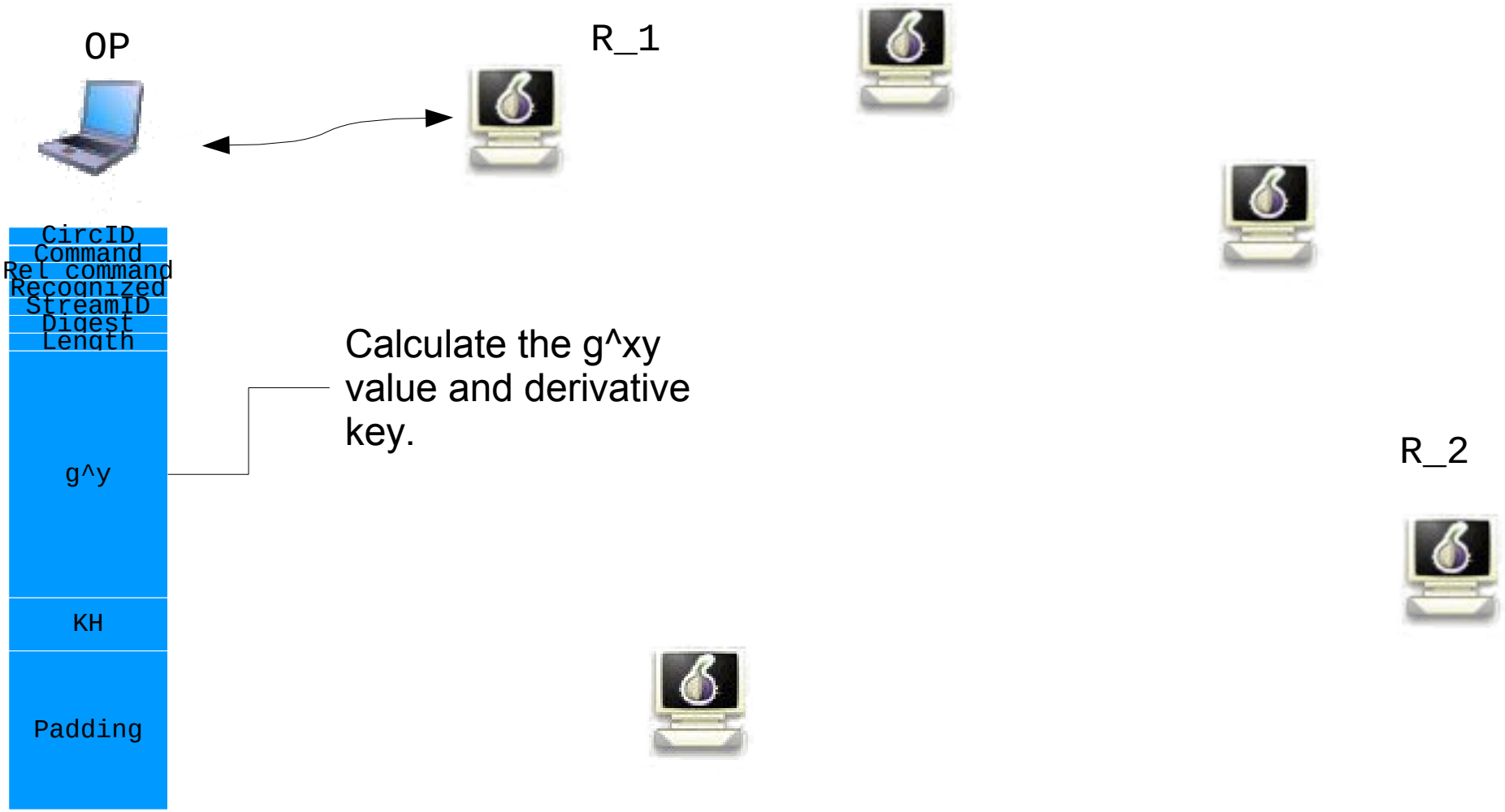


How Tor *in depth* works: Circuit



How Tor *in depth* works: Circuit



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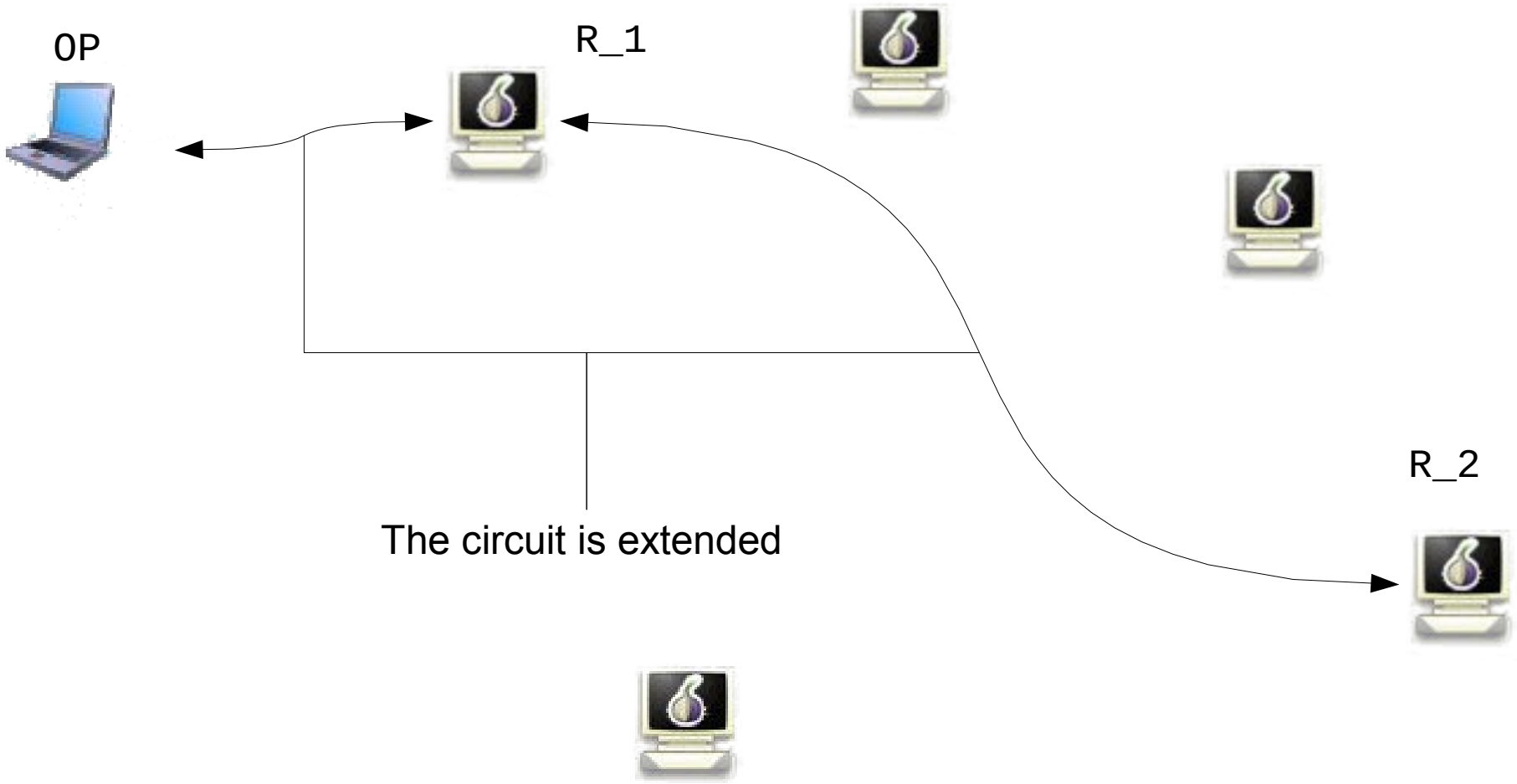


How Tor *in depth* works: Web traffic

Tor use the socks4 proxy interface.

SOCKS4 is an Internet protocol that allows client-server applications to transparently use the services of a network firewall.

So we can send thought TOR almost ALL TCP TRAFFIC!!!

We only need to “torify” the applications we would use.

Often it would mean simply set up proxy to localhost port 9050.

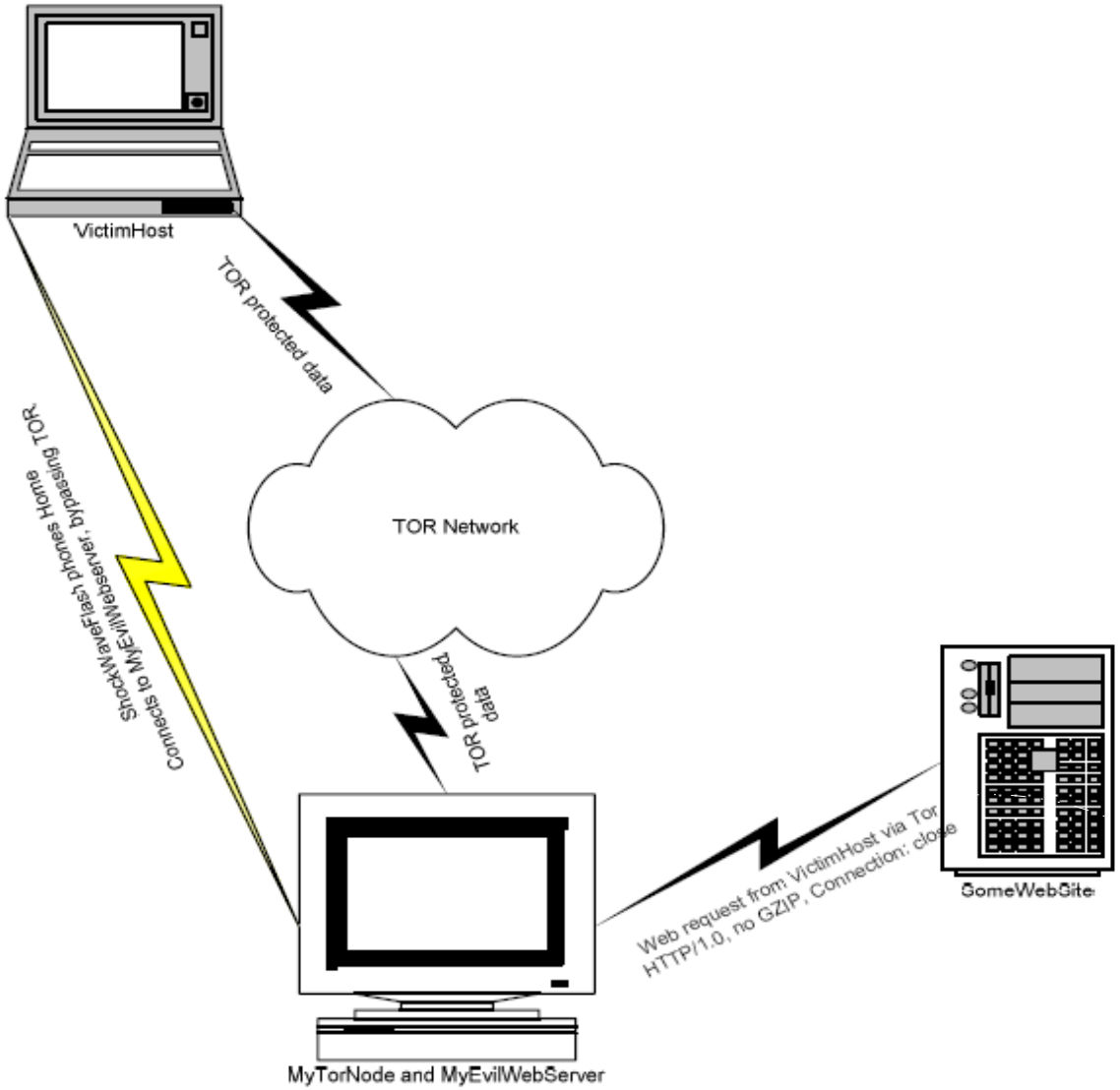
Open Problems: Phone Home

There's no evident problems in TOR implementation.
It assure that all the tenets enunciated in the TOR design paper are respected.

But ... there are other technologies that, used together, cause

- a web browser using TOR to “Phone Home” ***outside*** the TOR network
- a web browser using TOR to “Phone home” ***inside*** the TOR network, and deliver uniquely-identifying about the client, such as the computer's hostname and IP address.

Open Problems: Phone Home



Open Problems: Phone Home

SOLUTIONS?

Yes

Use “NoScript” plugin for Firefox...

nothing for IE (did you expect this?)

References:

- Carmelo Badalamenti - “TOR: Design e Simulazione”, Relatore prof. G. Bella, Relazione Stage
- Roger Dingledinen - “Tor:Anonymous Communications for the United States Department of Defence..and you.” July 2005
- Andrei Serjantov - “On the anonymity of anonymity systems”, October 2004
- Roger Dingledine, Nick Mathewson - “Tor Protocol Specification”, October 2006
- Roger Dingledine, Nick Mathewson, Paul Syverson - “Tor: The Second-Generation Onion Router”, November 2005
- VVAA - Wikipedia, all time
- Fortconsult – “Practical Onion hacking, Finding the real address of TOR clients”, October 2006