Using Separation Logic for Proving Security Protocol Implementations Secure

Linard Arquint

Joint work with Malte Schwerhoff, Vaibhav Mehta, and Peter Müller

ETH zürich

ars TECHNICA BIZ & IT TECH SCIENCE POLICY CARS GAMING & CULTURE STORE

A GLITCH IN THE MATRIX —

Serious vulnerabilities in Matrix's end-to-end encryption have been patched

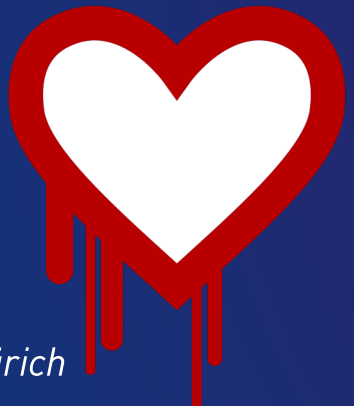
Previously overlooked flaws allow malicious homeservers to decrypt and spoof messages.

DAN GOODIN - 9/28/2022, 9:00 AM

A Traceability Attack against e-Passports

Tom Chothia* and Vitaliy Smirnov

School of Computer Science, University of Birmingham, Birmingham, UK



NEWS

Four cryptographic vulnerabilities in Telegram

An international research team of cryptographers completed a detailed security analysis of the popular Telegram messaging platform identifying several weaknesses in its protocol that demonstrate the product falls short of some essential data security guarantees.

16.07.2021 by Marianne Lucien

2 Comments

Existing Work

Protocol Model

Code Generation

Tamarin

ProVerif

DY*

Our Work

Existing
Implementations

Our Work


Mutable state
Heap manipulations
Complex control flow
Concurrency
Existing Implementations

Our Work

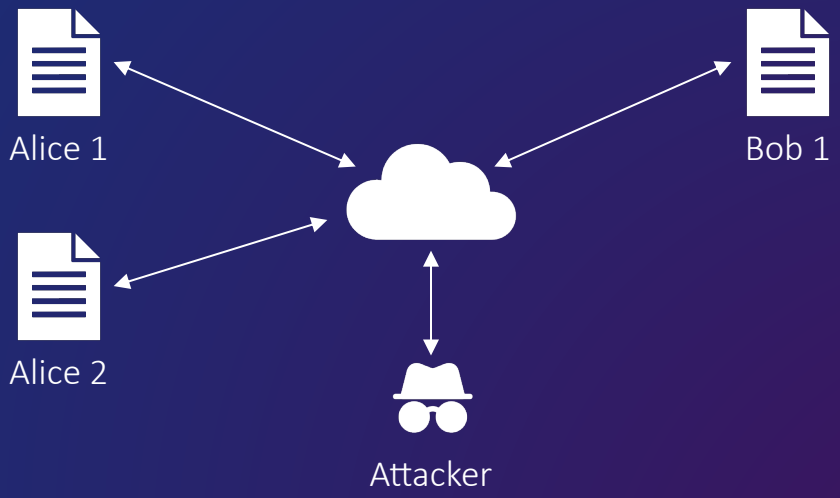
Existing
Implementations

Language agnostic

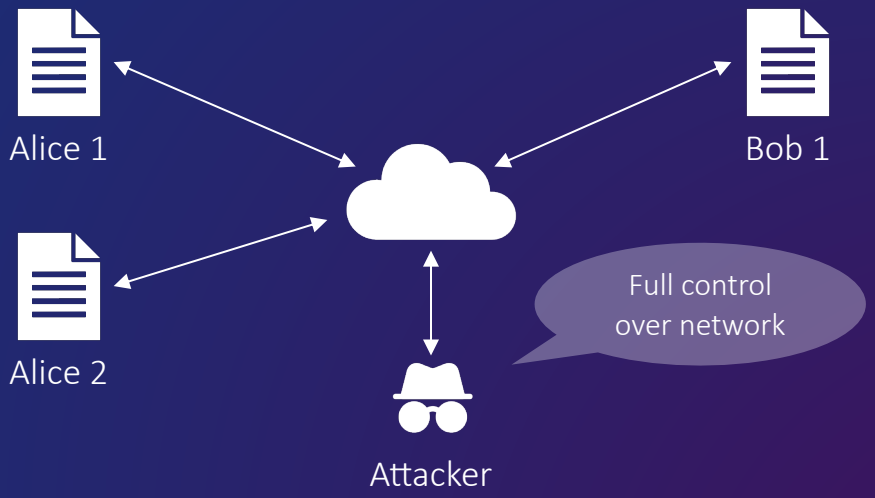
Verifier agnostic

Protocol agnostic

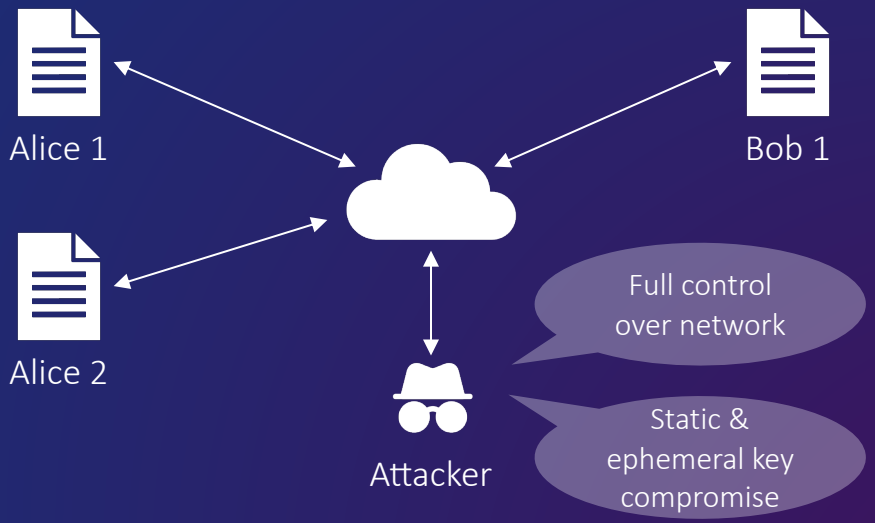
Approach



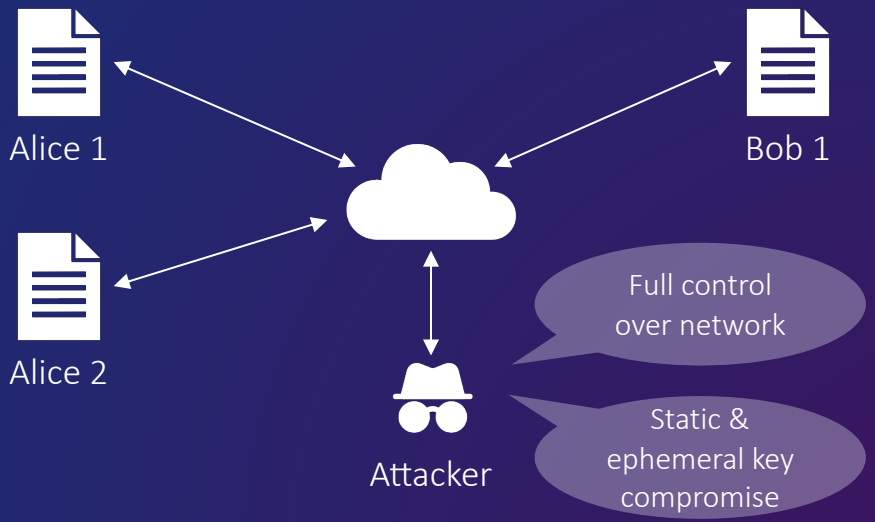
Approach



Approach

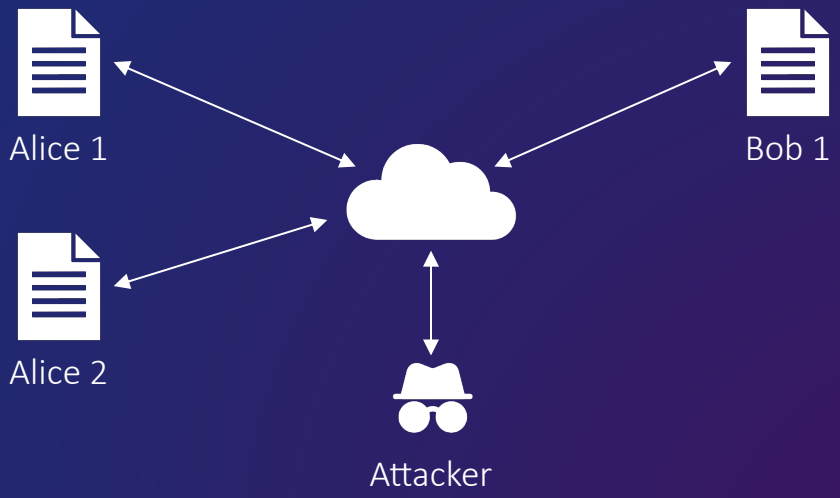

Alice 1
Bob 1
Alice 2
Attacker
Full control over network
Static & ephemeral key compromise

Approach



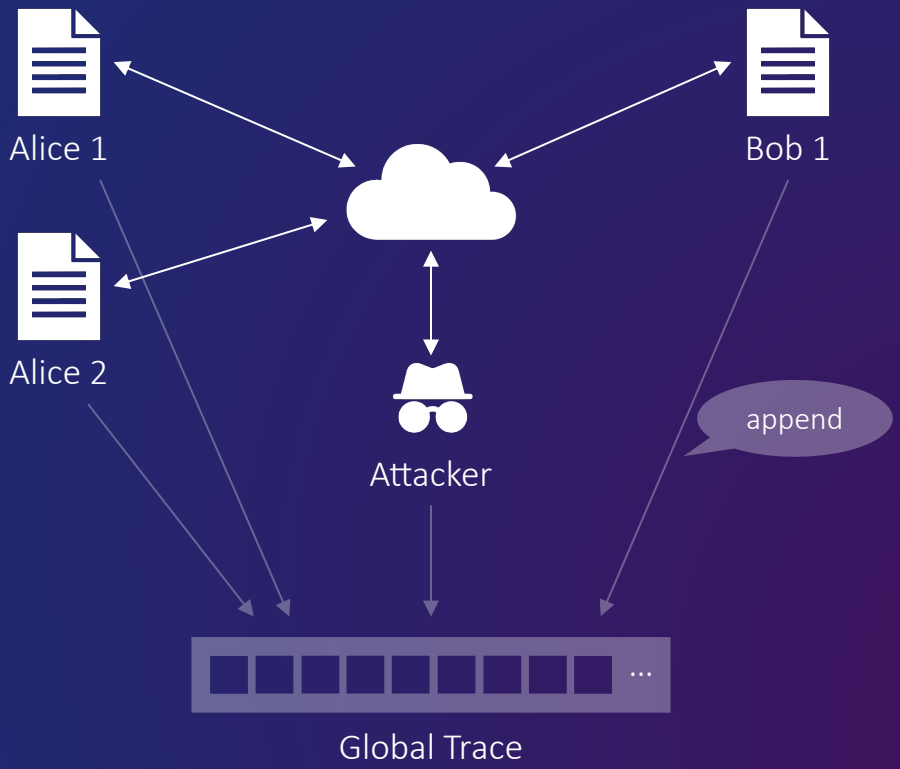
→ Model as a program with threads

Approach

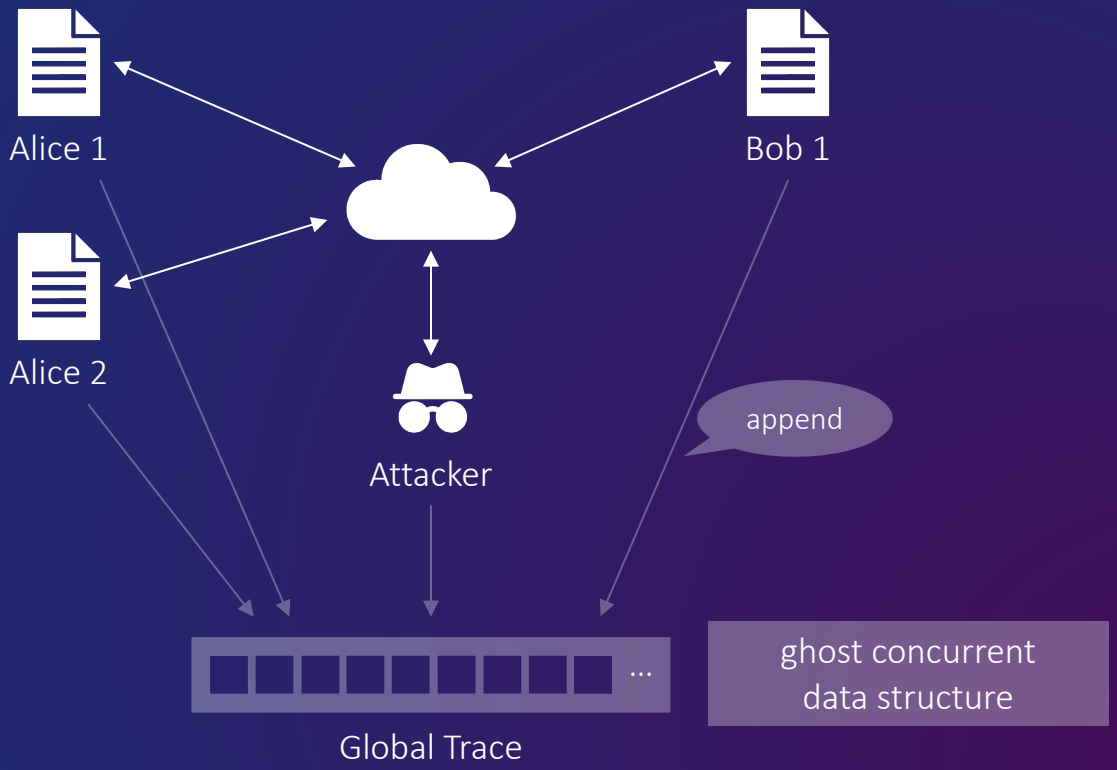


Global Trace

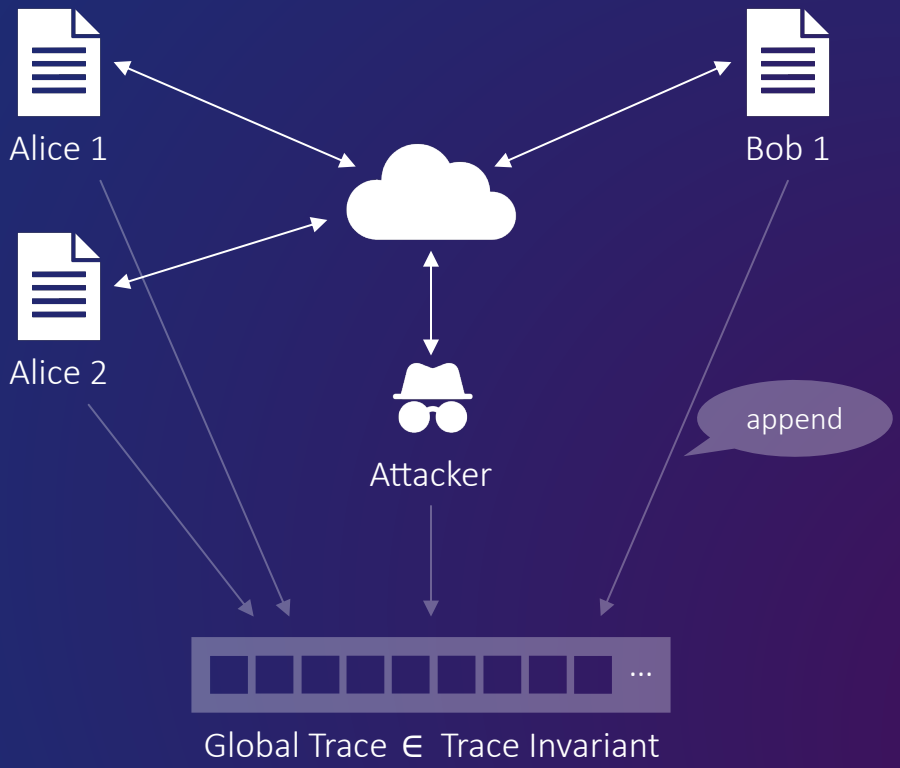
Approach



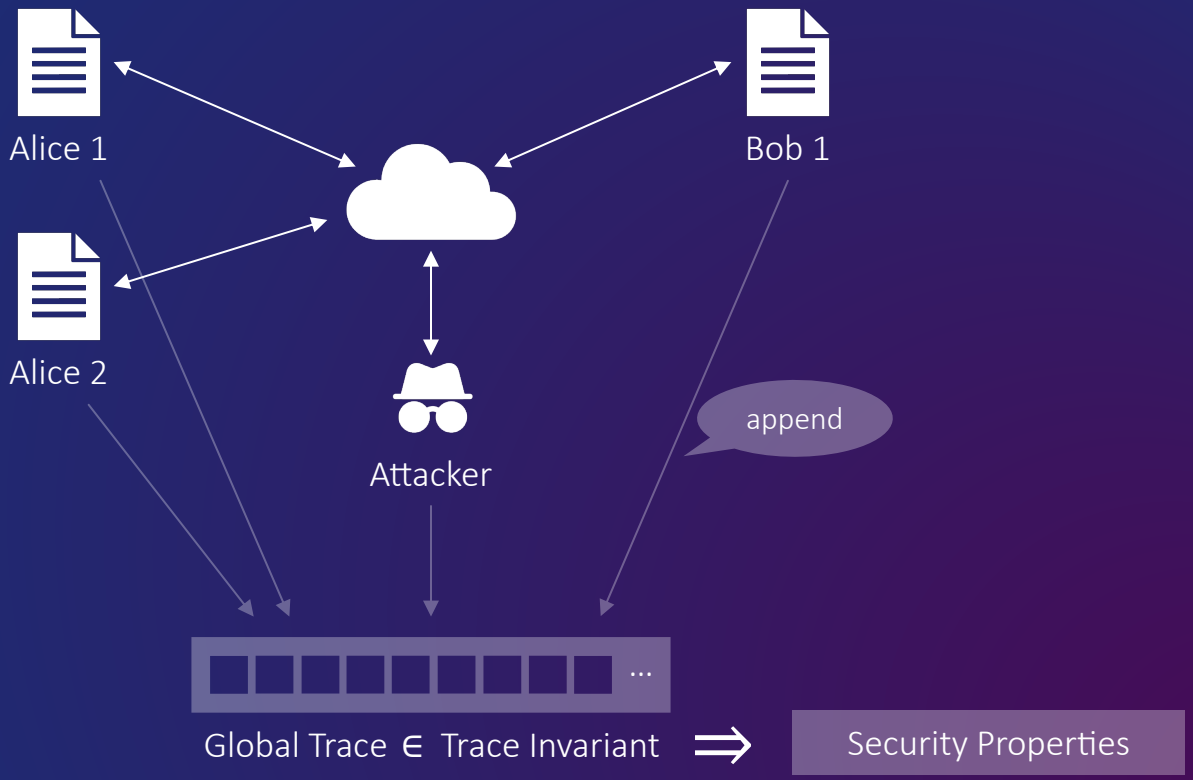
Approach


Alice 1
Bob 1
Alice 2
Attacker
append
...
Global Trace
ghost concurrent
data structure

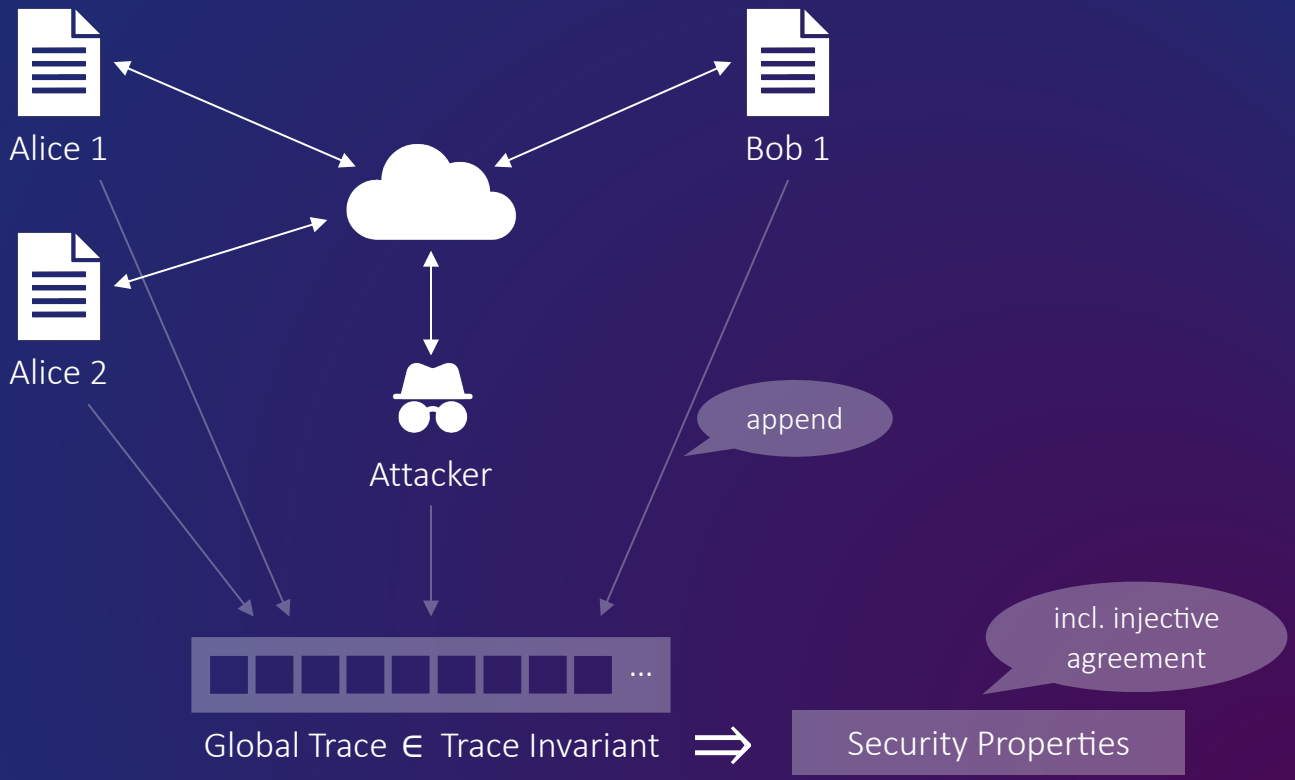
Approach

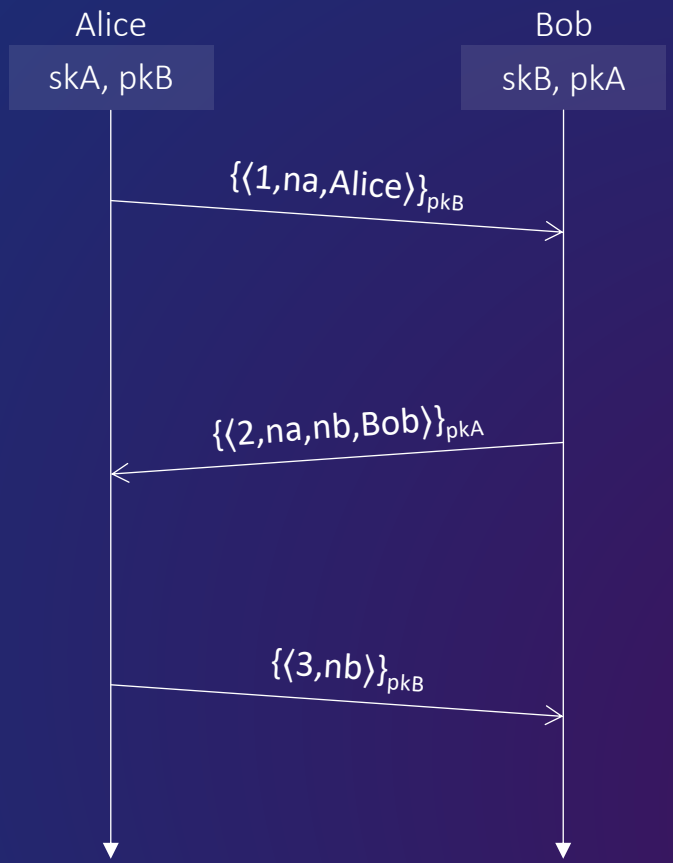

Alice 1
Bob 1
Alice 2
Attacker
append
...
Global Trace ∈ Trace Invariant

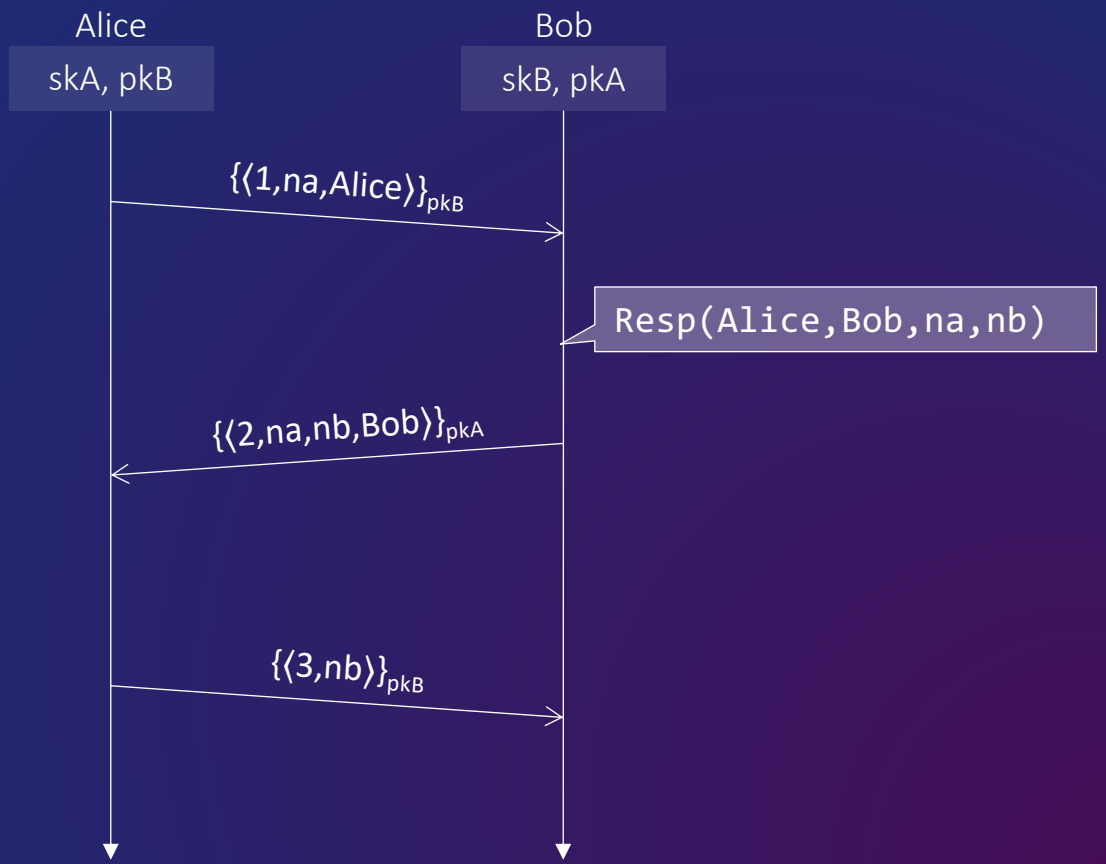
Approach

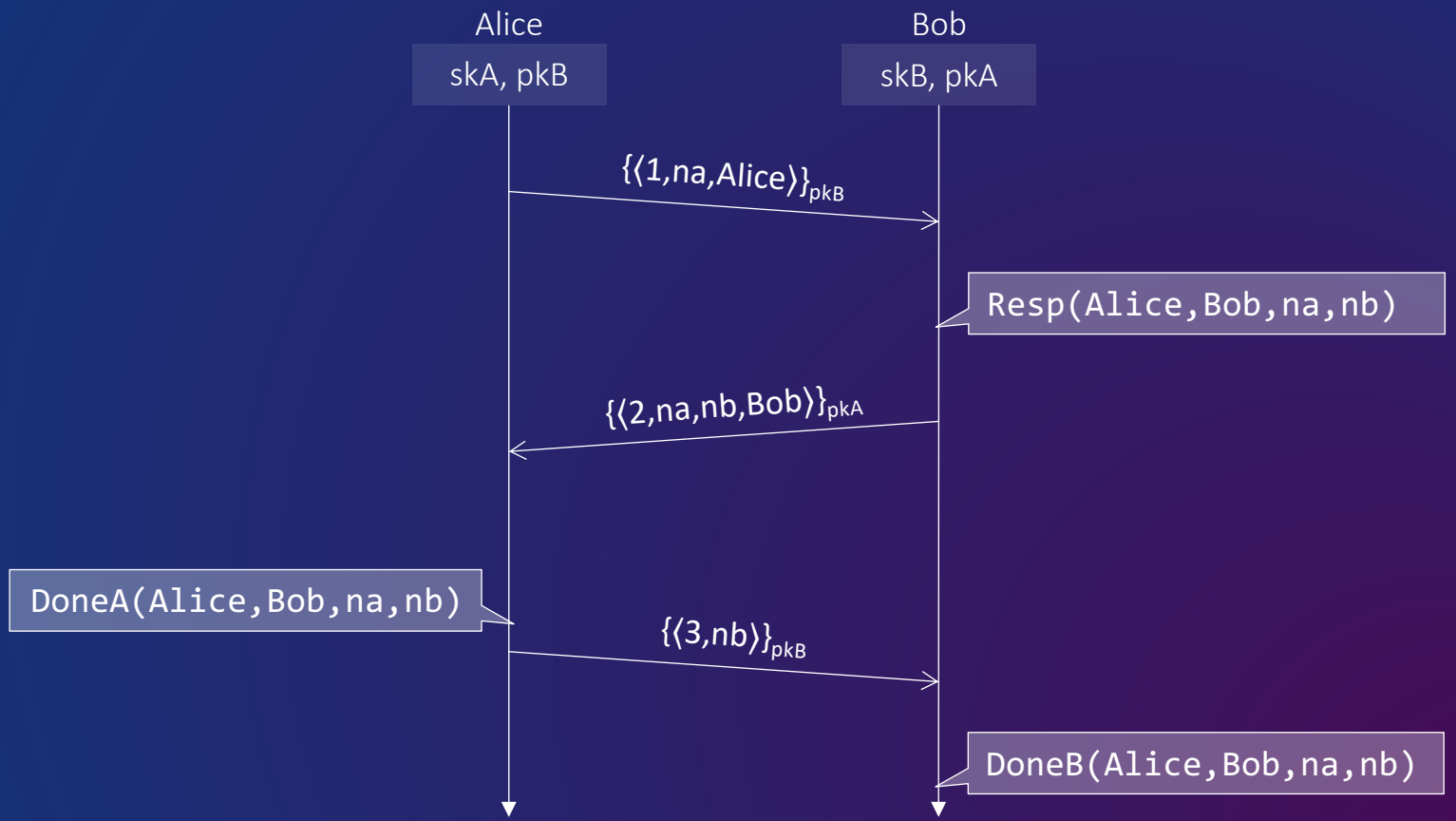

Alice 1
Bob 1
Alice 2
Attacker
append
...
Global Trace ∈ Trace Invariant
⇒
Security Properties

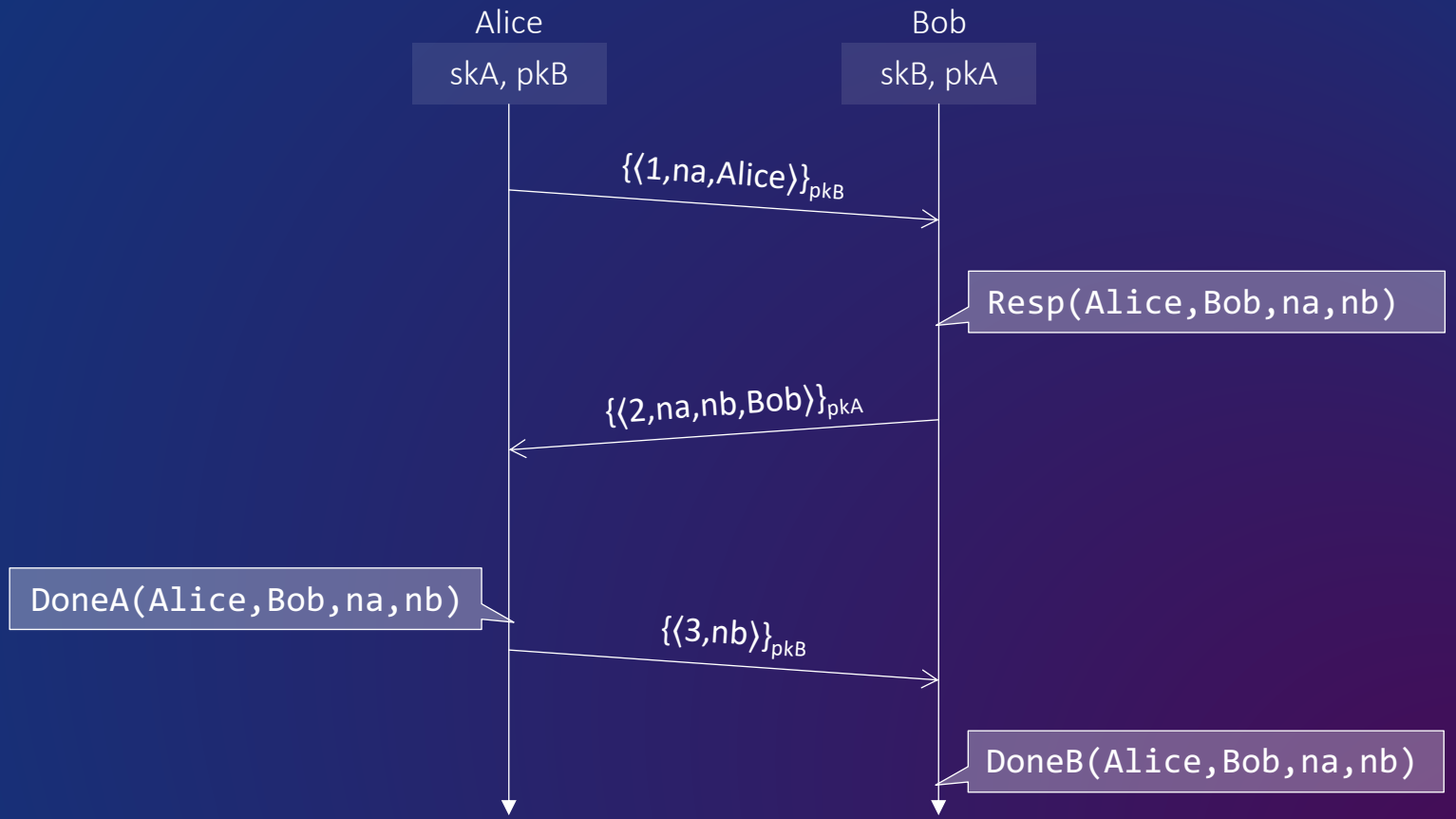
Approach


Alice 1
Bob 1
Alice 2
Attacker
append
...
Global Trace ∈ Trace Invariant
incl. injective agreement
Security Properties

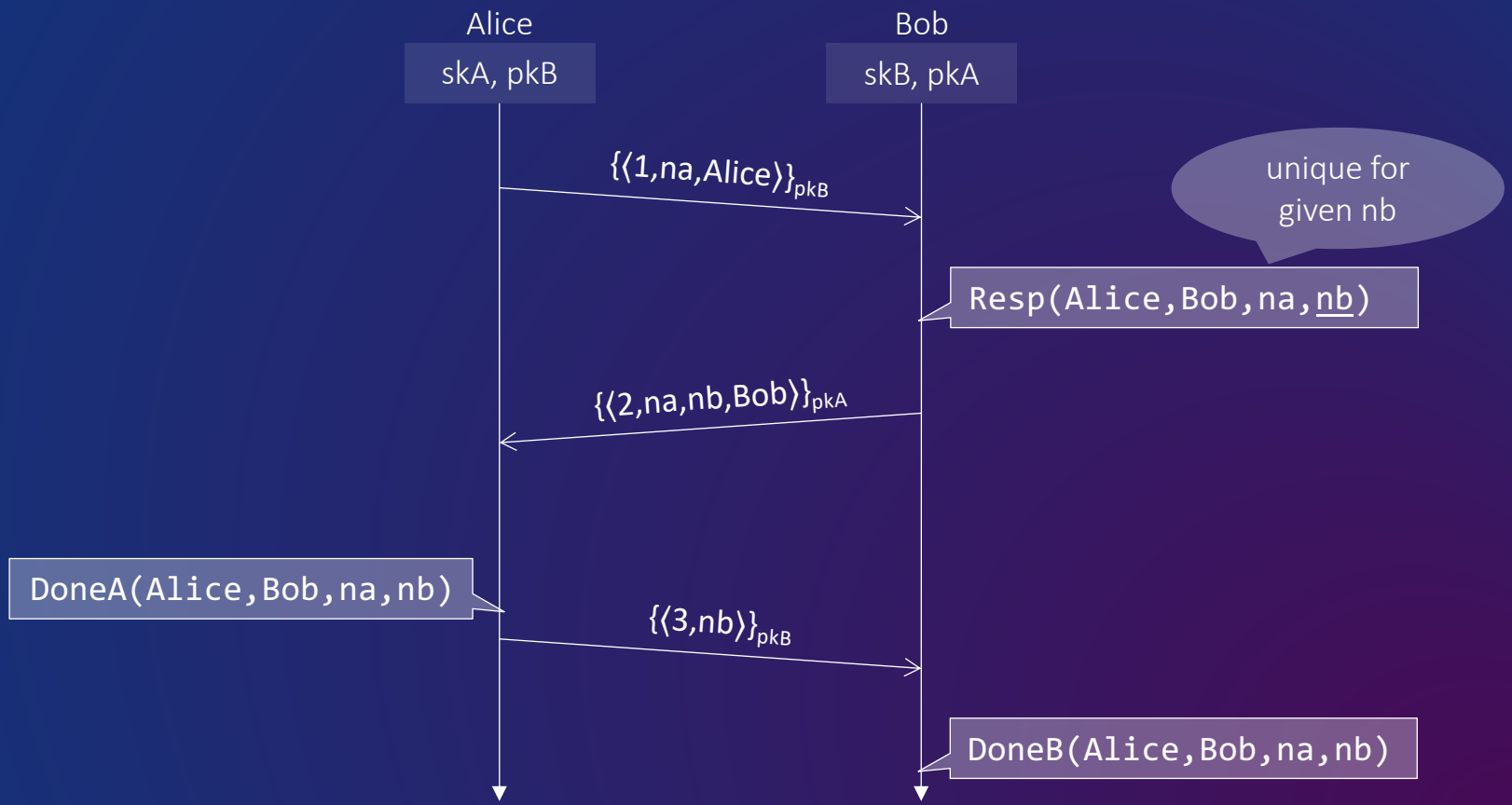

Alice
skA, pkB
Bob
skB, pkA
{⟨1,na,Alice⟩}pkB
{⟨2,na,nb,Bob⟩}pkA
{⟨3,nb⟩}pkB

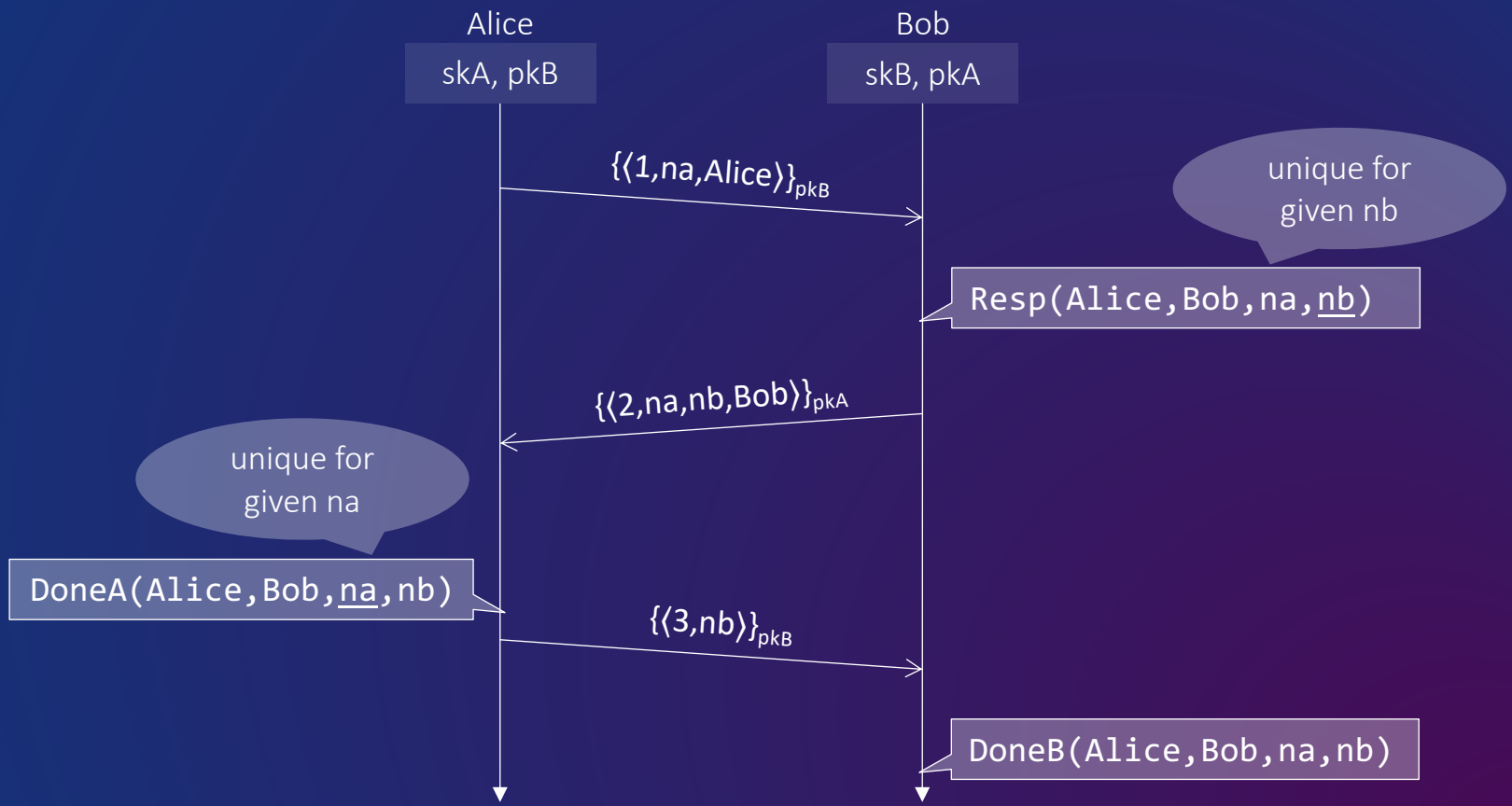

Alice
skA, pkB
Bob
skB, pkA
{⟨1,na,Alice⟩}pkB
Resp(Alice,Bob,na,nb)
{⟨2,na,nb,Bob⟩}pkA
{⟨3,nb⟩}pkB

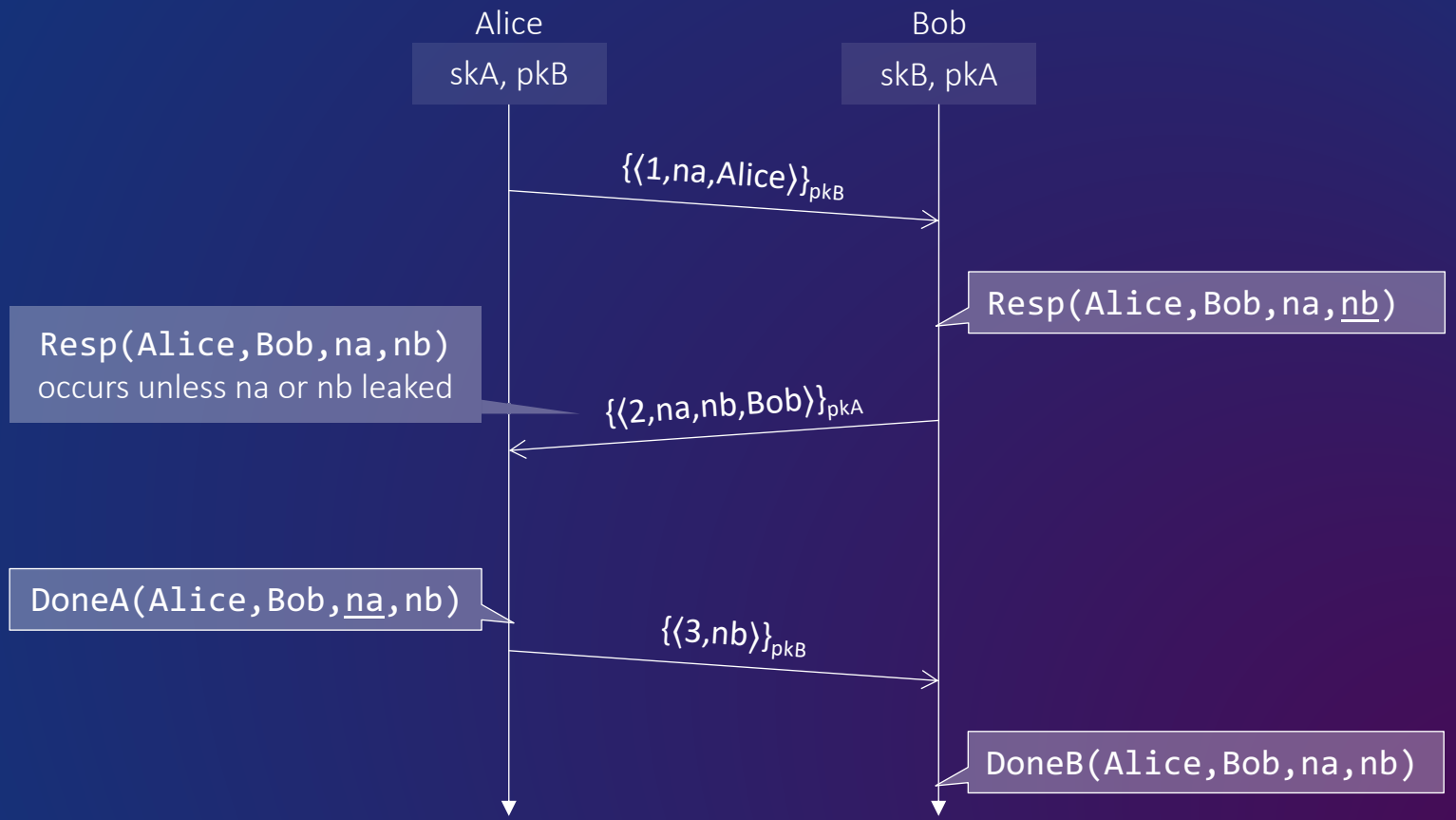

Alice
skA, pkB
Bob
skB, pkA
{⟨1,na,Alice⟩}pkB
Resp(Alice,Bob,na,nb)
{⟨2,na,nb,Bob⟩}pkA
DoneA(Alice,Bob,na,nb)
{⟨3,nb⟩}pkB
DoneB(Alice,Bob,na,nb)

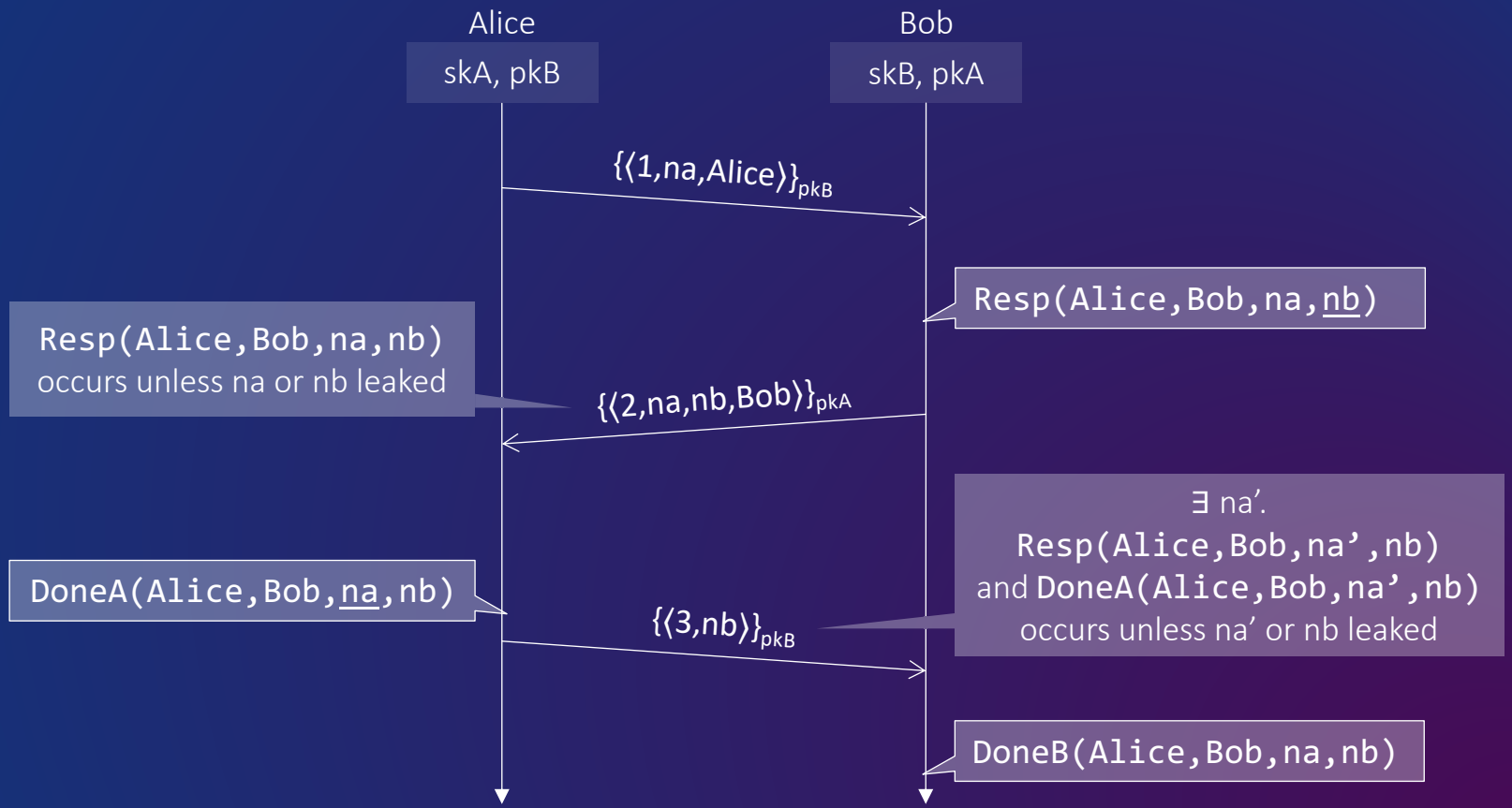


“ DoneB(Alice,Bob,na,nb) ⇒ Exactly one DoneA(Alice,Bob,na,nb)


Alice
skA, pkB
Bob
skB, pkA
{⟨1,na,Alice⟩}pkB
unique for given nb
Resp(Alice,Bob,na,nb)
{⟨2,na,nb,Bob⟩}pkA
DoneA(Alice,Bob,na,nb)
{⟨3,nb⟩}pkB
DoneB(Alice,Bob,na,nb)


Alice
skA, pkB
Bob
skB, pkA
{⟨1,na,Alice⟩}pkB
unique for given nb
Resp(Alice,Bob,na,nb)
{⟨2,na,nb,Bob⟩}pkA
unique for given na
DoneA(Alice,Bob,na,nb)
{⟨3,nb⟩}pkB
DoneB(Alice,Bob,na,nb)


Alice
skA, pkB
Bob
skB, pkA
{⟨1,na,Alice⟩}pkB
Resp(Alice,Bob,na,nb)
Resp(Alice,Bob,na,nb)
occurs unless na or nb leaked
{⟨2,na,nb,Bob⟩}pkA
DoneA(Alice,Bob,na,nb)
{⟨3,nb⟩}pkB
DoneB(Alice,Bob,na,nb)


Alice
skA, pkB
Bob
skB, pkA
{⟨1,na,Alice⟩}pkB
Resp(Alice,Bob,na,nb)
Resp(Alice,Bob,na,nb)
occurs unless na or nb leaked
{⟨2,na,nb,Bob⟩}pkA
∃ na'.
Resp(Alice,Bob,na',nb)
and DoneA(Alice,Bob,na',nb)
occurs unless na' or nb leaked
DoneA(Alice,Bob,na,nb)
{⟨3,nb⟩}pkB
DoneB(Alice,Bob,na,nb)

```
func main(pkB []byte) {
  n := random()
  msg := enc(n, pkB)
  send(msg)
}
```

Alice

```
func send(msg) {




  io.send(msg)
}
```

Library

Global Trace ∈ Trace Invariant

\+

I/O

```
func main(pkB []byte) {
  n := random()
  msg := enc(n, pkB)
  send(msg)
}
```

Alice

```
func send(msg) {
  //@ trace.lock()
  //@ trace.append(Send(msg))
  //@ trace.unlock()

  io.send(msg)
}
```

Library

Global Trace ∈ Trace Invariant

+

I/O

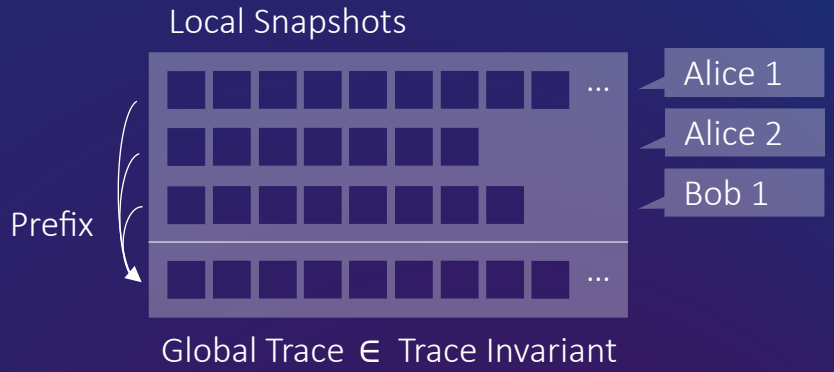
```
func main(pkB []byte) {
  n := random()
  msg := enc(n, pkB)
  send(msg)
}
```

Alice

```
func send(msg) {
  //@ trace.lock()
  //@ trace.append(Send(msg))
  //@ trace.unlock()


  io.send(msg)
}
```

Library



+

I/O

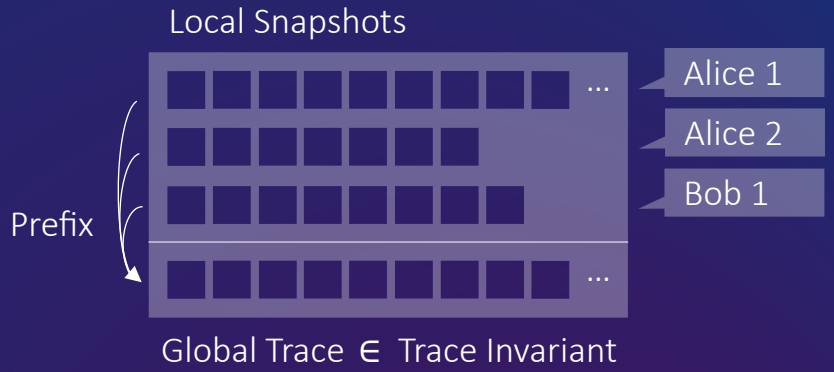
```
func main(pkB []byte) {
  n := random()
  msg := enc(n, pkB)
  send(msg)
}
```

Alice

```
func send(msg) {
  //@ trace.lock()
  //@ trace.append(Send(msg))
  //@ setSnap(trace)
  //@ trace.unlock()

  io.send(msg)
}
```

Library



+

I/O

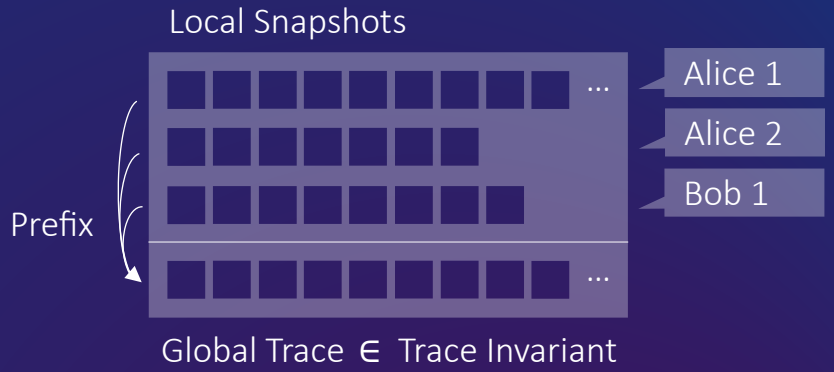
```
func main(pkB []byte) {
  n := random()
  msg := enc(n, pkB)
  send(msg)
}
```

Alice

```
//@ req msgInv(getSnap(), msg)
func send(msg) {
  //@ trace.lock()
  //@ trace.append(Send(msg))
  //@ setSnap(trace)
  //@ trace.unlock()

  io.send(msg)
}
```

Library



+

I/O

```
func main(pkB []byte) {
  n := random()
  msg := enc(n, pkB)
  send(msg)
}
```

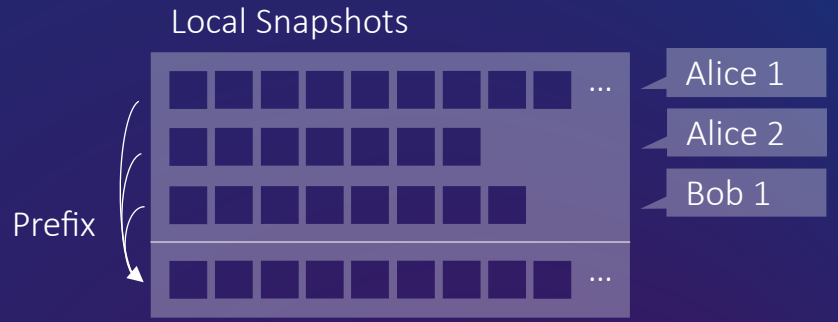
Alice

```
//@ req msgInv(getSnap(), msg)
func send(msg) {
  //@ trace.lock()
  //@ trace.append(Send(msg))
  //@ setSnap(trace)
  //@ trace.unlock()

  io.send(msg)
}
```

Library

Parameterized



+

I/O

Evaluation

Verification libraries for C & Go

Evaluation

Verification libraries for C & Go

Library	LOC	LOS	[s]
Go / Gobra	83	6,932	126.1
C / VeriFast	343	3,837	0.8

Evaluation

Verification libraries for C & Go

NSL (in C & Go) and
signed DH key exchange (in Go)

Evaluation

Verification libraries for C & Go

WireGuard VPN protocol

NSL (in C & Go) and
signed DH key exchange (in Go)

Evaluation

Verification libraries for C & Go

WireGuard VPN protocol

NSL (in C & Go) and
signed DH key exchange (in Go)

WireGuard	LOC	LOS	[s]
Go / Gobra	557	5,815	268.1

Evaluation

Verification libraries for C & Go

WireGuard VPN protocol

NSL (in C & Go) and
signed DH key exchange (in Go)

Inj. agreement and forward secrecy
proven for WireGuard

Evaluation

Verification libraries for C & Go

WireGuard VPN protocol

NSL (in C & Go) and
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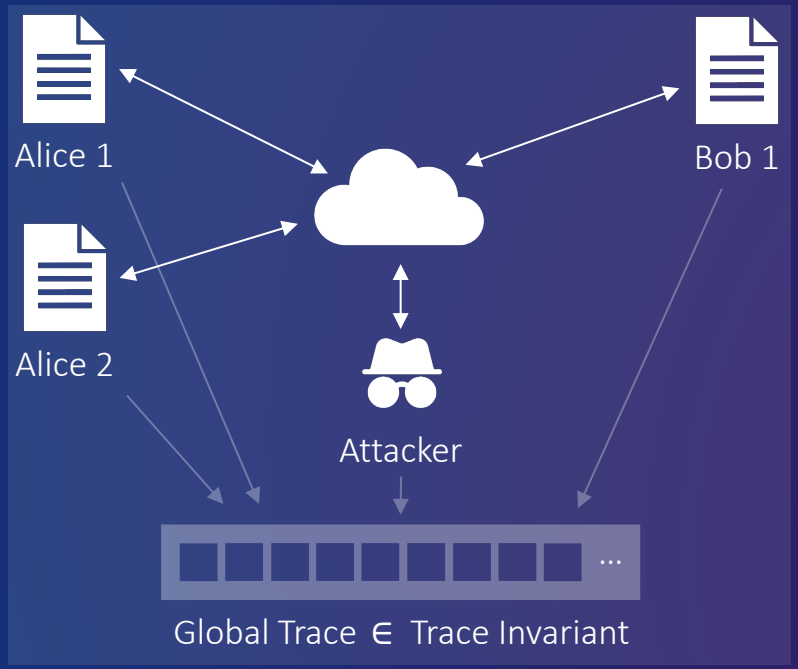
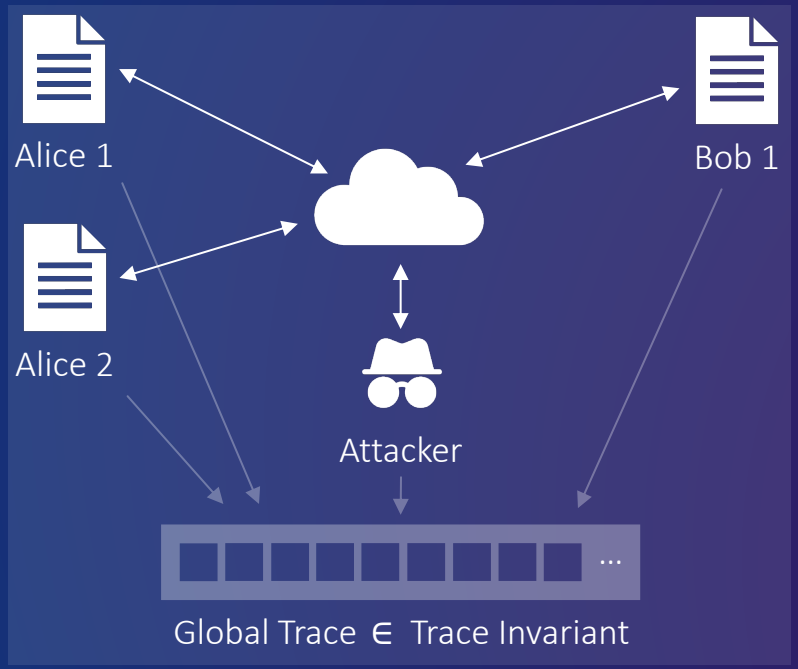
Inj. agreement and forward secrecy
proven for WireGuard

GitHub viperproject/SecurityProtocolImplementations

Conclusions

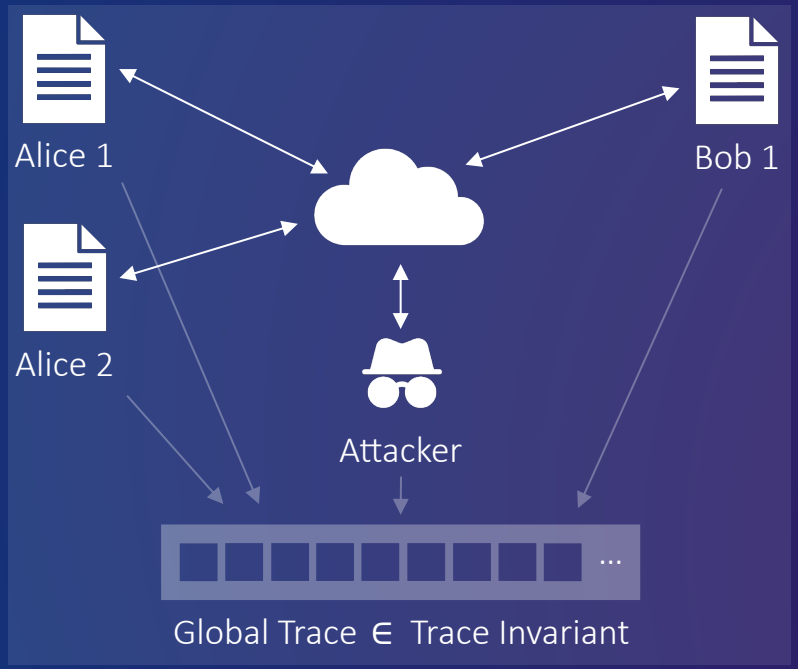


Conclusions



WireGuard

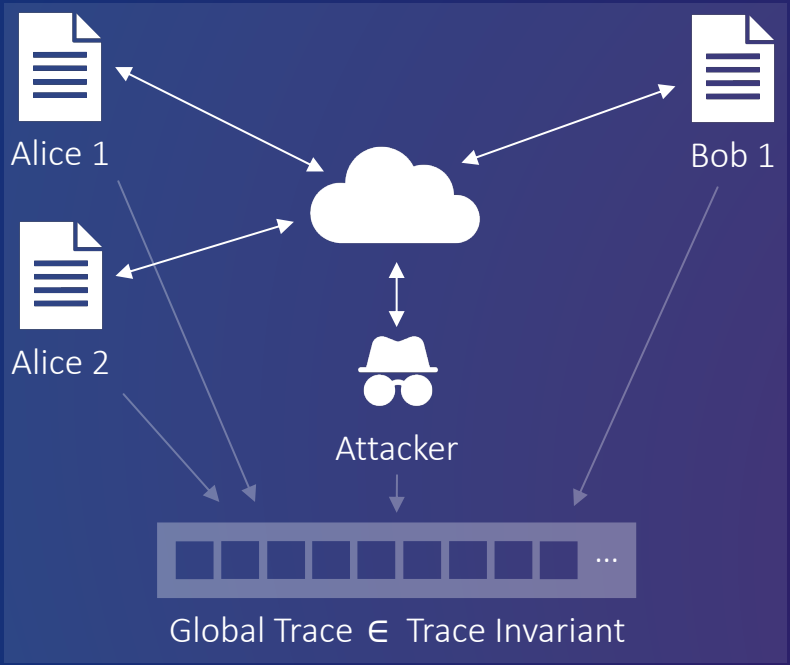
Conclusions



WireGuard

CCS ‘23: A Generic Methodology for the Modular Verification of Security Protocol Implementations

Conclusions



WireGuard

CCS ‘23: A Generic Methodology for the Modular Verification of Security Protocol Implementations

Soundness proof