Decentralized Business Networks: Security

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Decentralized Business Networks: Security

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- Huge attack vector

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Decentralized

- Non-trivial wrt. enforcement, accountability, etc.

Decentralized Business Networks: Security (Continued)

Two levels of attack surfaces

- **Infrastructure-level:** What happens outside the protocol
- **Communication-level:** What happens inside the protocol

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Infrastructure-level security

- Threat Model: External attackers (MitM, replay, tampering, etc.)
- Policy: Confidentiality, integrity, availability
- Mechanism: Encryption, signatures, nonces
- Assurance: Vetted off-the-shelf solutions

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- **Infrastructure-level:** What happens outside the protocol
- **Communication-level:** What happens inside the protocol

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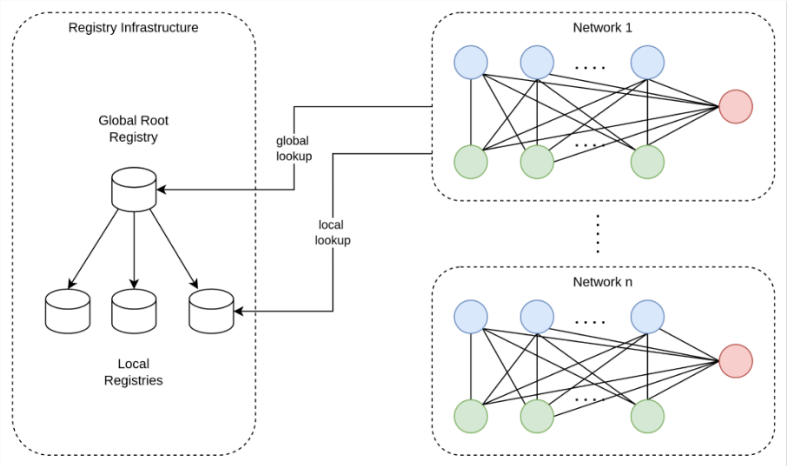
Communication-level security

- Threat Model: Internal (protocol-conforming) attackers
- Policy: Privacy, availablity, fraud-avoidance, etc.
- Mechanism: Protocol specification, properties, and conformance
- Assurance: Certification, sampling, traffic analysis

Beckn Architecture

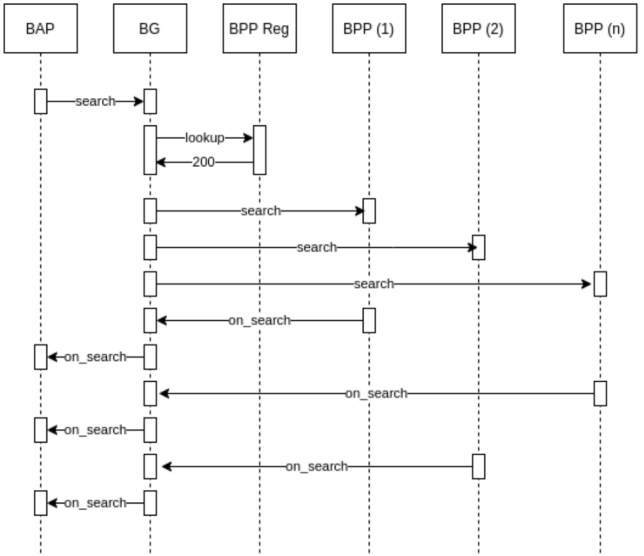


Blue: Buyers (BAPs), Green: Sellers (BPPs), Red: Gateways (BGs)

Beckn API

Stage	Method	Description	Returns
Discovery	`search`	declare intent	catalog
Order	`select`	draft order	quote
	`init`	shipping/billing info	payment terms
	`confirm`	confirm order	acknowledgment
Fulfillment	`status`	get order	order details
	`track`	track order	tracking details
	`update`	update order	acknowledgment
	`cancel`	cancel order	acknowledgment
Post-Fulfillment	`rating`	provide rating	acknowledgment
	`support`	request support	support info

Beckn Protocol - Discovery



Scenario 1: Privacy

Disclaimer: Not necessarily a vulnerability in the current version of Beckn

Scenario:

I make two separate searches: A taxi to my home and <SENSITIVE>

The seraches are broadcasted to all eligible sellers

I only get offers from legit-looking sellers, and simply choose two of them

Later I receive blackmail threatening to expose that I like <SENSITIVE>

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Problem: Searches reveal BAP identity, participation is optional
Possible Solution: Dont inform sellers of my identity until I accept their offer

Scenario 2: Availability

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Problem: Mallory can make offers that are effectively irrelevant
Possible Solution: Determine and rule out "irrelevant" offers

Key Takeaways

Security violations in decentralized networks are subtle, e.g.

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Our Opinion: Formal specifications should be a requirement
Research Question: Is this even feasible?
Our Contribution: Yes it is (to some extend)

Our Contribution: An Approach to Formality in Decentralized Networks

Demonstrated through the Beckn Protocol

Overivew of Approach

Protocol specification

- Formal model of messages
- Formal model of message requirements (assumptions)
- Formal model of interactions

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- (In)formal proofs: Testing, deductive proof systems, mechanisation

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Protocol conformance

- Informal: Certification, sampling, traffic analysis
- Semi-formal: Runtime monitoring
- Formal: Static analysis

A Formal Model of Messages

Conventional Type Theory:

$$\tau ::= \mathbb{Z} \mid \mathbb{R} \mid \mathsf{String} \mid \tau_1 \times \tau_2 \mid \{x_1 : \tau_1, \ldots, x_n : \tau_n\} \mid \ldots$$

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Examples of Messages (Taxi Service):

$$\begin{aligned} \text{Intent} &::= \{\mathit{fulfillment} : \text{Fulfillment}\} \\ \text{Fulfillment} &::= \{\mathit{start} : \text{Location}, \mathit{end} : \text{Location}\} \\ \text{Location} &::= \{\mathit{gps} : \mathbb{R} \times \mathbb{R}\} \end{aligned}$$

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$$\begin{aligned} \text{Catalog} &::= \{\mathit{providers} : \text{List Provider}\} \\ \text{Provider} &::= \{\mathit{id} : \text{String}, \mathit{items} : \text{List Item}\} \\ \text{Item} &::= \{\mathit{id} : \text{String}, \mathit{price} : \mathbb{Z}, \mathit{location} : \text{Location}, \mathit{eta} : \mathbb{Z}\} \end{aligned}$$

A Formal Model of Requirements

Conventional Logical Propositions:

$$P, Q ::= \mathsf{True} \mid \mathsf{False} \mid P \wedge Q \mid P \vee Q \mid \forall x \in \tau.\, P \mid \exists x \in \tau.\, P \mid \ldots$$

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Example of Propositional Requirement (Taxi Service):

$$\begin{aligned}&\mathsf{ValidCat}\,(\mathit{int} : \mathsf{Intent})\,(\mathit{cat} : \mathsf{Catalog}) \triangleq \\ &\quad \forall \mathit{provider} \in \mathit{cat}.\mathit{providers}.\forall \mathit{item} \in \mathit{provider}.\mathit{items}. \\ &\qquad \mathtt{distance}(\mathit{int}.\mathit{fulfillment}.\mathit{start}, \mathit{item}.\mathit{location}) < \mathtt{MAX\_DIST}\end{aligned}$$

A Formal Model of Decentralized Protocols

Dependent Session Protocols:

$$
\begin{aligned}
p ::= \; & \mathbf{!}\,[i]\,(\vec{x}:\vec{\tau})\,\langle v\rangle\{P\}.\,p \mid \\
& \mathbf{?}[i]\,(\vec{x}:\vec{\tau})\,\langle v\rangle\{P\}.\,p \mid \\
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Example of Protocol (Any Network):

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&\mathsf{BPP} \triangleq \Sigma_{G\in Gs}. \\
&\quad \mathbf{?}[G]\,(int : \mathsf{Intent})\,\langle int\rangle. \\
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Treats message types and requirements abstractly!:

$$M ::= \mathsf{Intent} \mid \mathsf{Catalog} \mid \ldots \qquad\qquad R ::= \mathsf{ValidCat}\;\mathit{int}\;\mathit{cat} \mid \ldots$$

A Formal Model of the Beckn Protocol

Beckn Protocol - Discovery Phase:

$\mathsf{BAP} \triangleq \Sigma_{G \in Gs}.$
$\quad !\,[G]\,(int : \mathsf{Intent})\,\langle int \rangle.\,\mathsf{BAP}'\,G$

$\mathsf{BAP}'\,G \triangleq$
$\quad ?[G]\,(b : \mathbb{B})\,(cat : \mathsf{Catalog})\,\langle (b, cat) \rangle \{\mathsf{ValidCat}\,int\,cat\}.$
$\quad \mathbf{if}\,b\,\mathbf{then}\,\mathbf{end}\,\mathbf{else}\,\mathsf{BAP}'\,G$

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Beckn Protocol - Order Phase:

$\mathrm{BAP\_ord}\,(cat : \mathrm{Catalog}) \triangleq$
$\quad !\,[S]\,(sel : \mathrm{Selection})\,\langle sel \rangle \{\mathrm{ValidSel}\,sel\,cat\}.$
$\quad ?[S]\,(ord : \mathrm{Order})\,\langle ord \rangle \{\mathrm{ValidOrd}\,ord\,sel\}.$
$\quad !\,[S]\,(bil : \mathrm{Billing})\,\langle ord <| bil \rangle.$
$\quad ?[S]\,(pay : \mathrm{Payment})\,\langle ord <| bil <| pay \rangle.$
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Protocol Properties

Protocol Consistency

- Provable property that all exchanges are consistent
- Variables, message, and requirements of receivers are met by senders
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Mechanised in the Rocq Prover

Protocol Conformance

Actris: Program Logic for Dependent Session Protocols

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$$\left\{c \rightarrowtail \mathbf{!}\,[i]\,(\vec{x}:\vec{\tau})\,\langle v\rangle\{P\}.\,p * P[\vec{t}/\vec{x}]\right\}\,c[i].\mathbf{send}(v[\vec{t}/\vec{x}])\,\left\{c \rightarrowtail p[\vec{t}/\vec{x}]\right\}$$

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OBS: Only applied and proven sound wrt operational semantics of simple research-centric programming languages

Conclusion

Decentralized networks are prone to security violations

- Even a lack of response can have implications
- It is not obvious what a protocol violation means

Formal protocols give a precise description

- Rigid policy for which we can prove properties and enforce conformance

Dependent session protocols is a candidate formal language

- Permits specifying dependent interactions between multiple participants
- Has infrastructure to prove protocol consistency and conformance
- Was sufficient for formalising a part of the Beckn protocol

Thank You

Questions?