Speech Acts and Tokens for Access Control and Provenance Tracking

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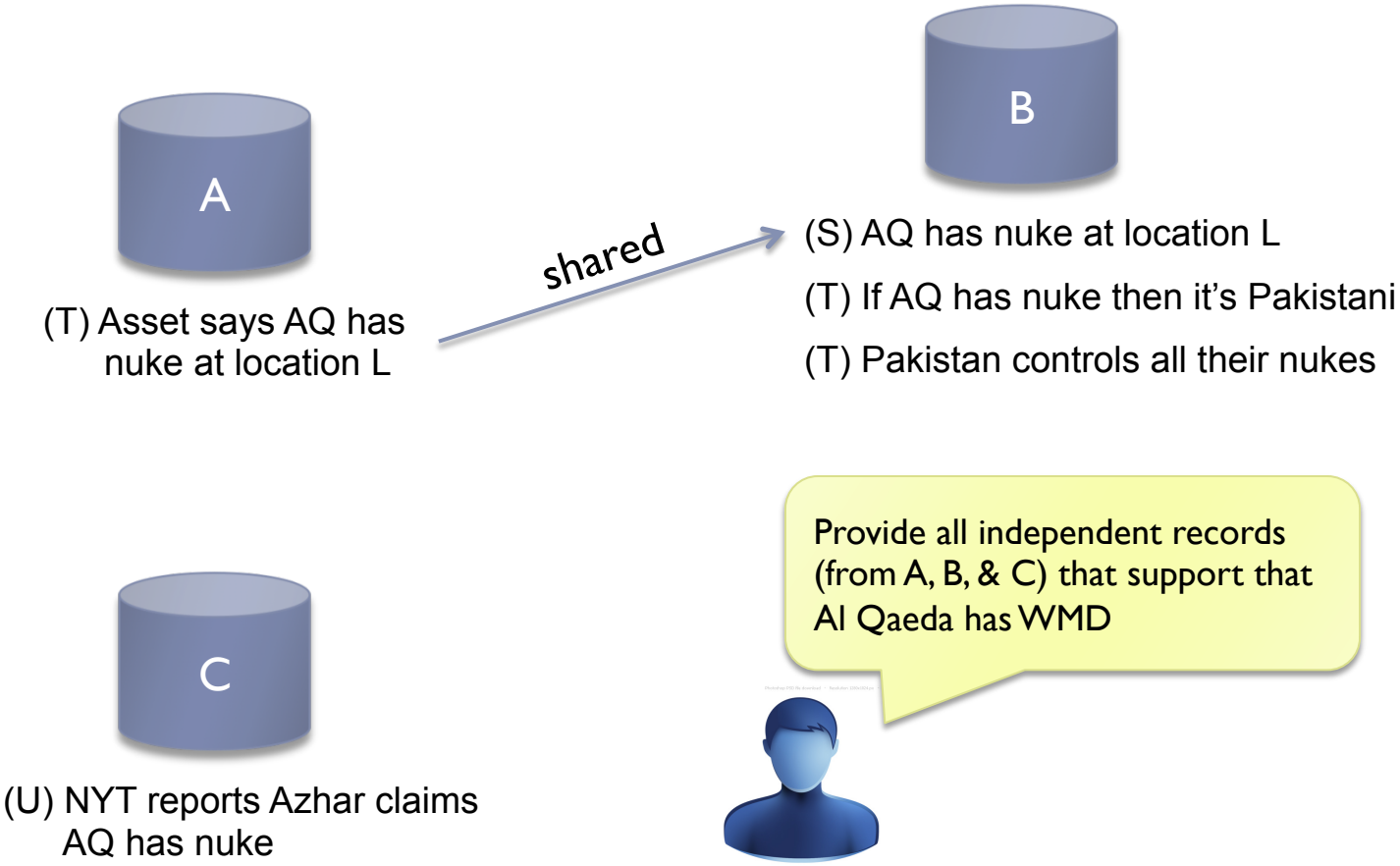
Sorry

Fabian can't be with us today …

Problem Statement

- Stock semantic technology works well where:
  - There is trust among producers and consumers of data
  - There is little or no noise in the data
- Often these conditions don't hold
  - Intelligence, LE, engineering, health care, E-science
- Such applications are characterized by
  - Multiple data sources
  - Need to protect sources and methods
  - Need to protect privacy
  - Need to control release of sensitive information
  - Need to support consumer confidence in integrated data

Motivating example



What is the right answer?

- It is not the "information" (propositions) that are protected, but the records (tokens) in each system
  - The right answer depends on access controls
- Source systems understand where their records came from to avoid duplication and false corroboration
  - The right answer depends on provenance
- We addressed these issues at STIDS 2009
- Here is what's new:
  - Hearsay (source of data external to provenance control)
  - Logical inconsistency
  - More about hearsay later

(Onto)logical approach

- Ontology
  - Formal languages
  - Propositions
  - Sentence types
  - Sentence tokens
  - Speech acts
- Formal System
  - Proof calculus
  - Axiomatization of supportedBy relation

Ontology

- Basic unit is the sentence token (of a formal language)
  - Need not be overtly logical
  - DBs, for example, will do
- We consider only formal languages here
  - …not restricted to overtly logical languages
- Sentence types encode propositions
- Sentence tokens are material objects
  - …or constituted of material objects (ask me offline)
- Sentence tokens instantiate sentence types
- Speech acts

Kinds of provenance

- IT processing tracking
  - Records history of operations on tokens inherent to operation of the information system
  - Examples
    - Copying
    - Algorithmic transformations
    - Automated theorem proving
- Hearsay tracking
  - Records history of tokens as originating from agents' communicative speech acts
  - Intention is essential to this view

About speech acts

- With typical deductive systems, we simply "insert" data without any further consideration of the act of assertion
  - Except perhaps recording transaction time, etc
- Speech acts are intentional acts by which linguistic tokens are brought into existence for achieving some type of communication
- We consider two types of speech acts
  - Assertive (updates)
  - Interrogative (queries)
- Speech acts provide the ontological foundation for individuation of assertions and queries

The formal system – preliminaries

- Deductive system that supports
  - Discretionary and mandatory access control
  - IT and "hearsay" provenance tracking
  - Privacy (not discussed in this work)
- Note
  - Direct implementation of this formal system not required to enjoy the benefits
  - Best to think of it as a specification of correct behavior that can be implemented in multiple ways

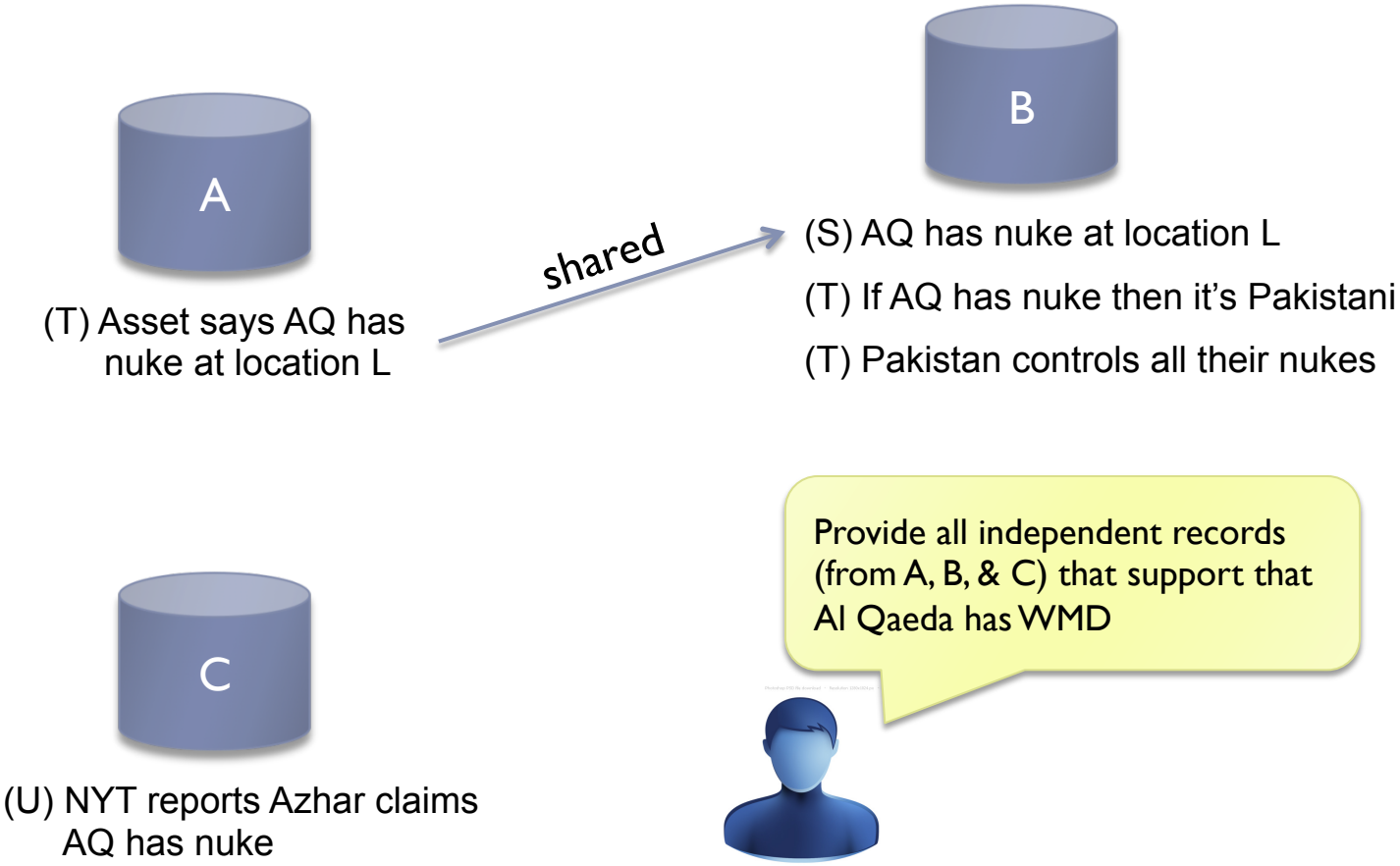
The formal system - details

- FOL system (Common Logic) as basis
- IKL-like extensions for proposition names
  - (that (likes fabian cookies))
  - Φ iff ((that Φ)) … for all formulas Φ
- Addition of two modal operators
  - $\Diamond \Phi$ – Φ is logically possibly true
  - $\Box \Phi$ – Φ is logically necessarily true
- A form of paraconsistent logic
  - Contradictions don't introduce chaos

Key non-logical vocabulary

- Record
  - a unary relation that ranges over tokens
- ResidesIn
  - a one-place function from tokens to systems
- PropositionalContent (PC)
  - a one-place function from tokens to propositions
- SupportedBy
  - a binary relation on propositions and token sequences
- BasedOn
  - A binary relation between tokens
- AssertionAct
  - a unary relation that ranges over assertive speech acts

Motivating example – refresher



Repository A

Record(token001) &
ResidesIn(token001) = repository_A &
ClassifiedAs(token001, TS) &
Compartment(token001, alQaeda_cmpt) &
Compartment(token001, proliferation_cmpt) &
CreatedBy(token001) = agent1234 &
PropositionalContent(token001) =
(that (∃ x (AssertionAct(x) &
Speaker(x, source007) &
Date(x) = 20.10.2011) &
PropositionalContent(x) =
(that (∃ y (Owns(alQaeda,y) & NuclWeap(y)))))

Assertive speech act records the claim of 007 that Al Qaeda has a nuclear weapon

Repository B

Record(token002) &
ResidesIn(token002) = repository_B &
ClassifiedAs(token002, S) &
BasedOn(token002, token001) &
ResidesIn(token001) = repository_A &
PropositionalContent(token002) =
(that (∃ x (AssertionAct(x) &
PropositionalContent(x) =
(that(∃ y (Owns (alQaeda y) & NuclWeap(y)))))

Repository C

```
Record(token003) &
ResidesIn(token003) = repository_C &
ClassifiedAs(token003, U) &
PropositionalContent(token003) =
    (that ( ∃ x (AssertionAct(x) &
                Speaker(x, nyt) &
                Date(x) = 23.10.2011 &
                PropositionalContent(x) =
                    (that ( ∃ y (AssertionAct(y) &
                                Speaker(y, Azhar) &
                                Date(y) = 22.10.2011 &
                                PropositionalContent(y) =
                                    (that ( ∃ z (Owns (alQaeda, z) &
                                                NuclWeap(z)))))
```

Three levels of "hearsay"

Axiomatization of SupportedBy

- Reflexivity
  - $(\mathrm{Record}(x) \;\&\; \Diamond \mathrm{PC}(x)) \rightarrow \mathrm{PC}(x)[x]$
- Axiomhood
  - $A \rightarrow A[]$
- And-introduction
  - $(A[s_1] \;\&\; B[s_2] \;\&\; \Diamond(A\&B)) \rightarrow (A\&B)[s_1 s_2]$
- Modus Ponens
  - $(A[s] \;\&\; \Box(A \rightarrow B)) \rightarrow B[s]$
- Hearsay
  - $(\Diamond A \;\&\; (\exists x(AA(x) \;\&\; \mathrm{PC}(x)=(\mathrm{that}\ A)))[s]) \rightarrow A[s]$

A[s] is shorthand for SupportedBy(A,s) where s is a sequence of tokens

A query and one answer

Query: $\exists x(\text{Owns}(\text{alQaeda } x) \,\&\, \text{WMD}(x))[?s]$

Proof:

1) $\forall x(\text{NuclWeap}(x) \rightarrow \text{WMD}(x))[\,]$
2) $\exists x(\text{AssertionAct}(x) \,\&\, \text{Speaker}(x \text{ source007}) \,\&\, \text{Date}(x) = 20.10.2011) \,\&$
   $\text{PropositionalContent}(x) = (\text{that}(\exists y(\text{Owns}(\text{alQaeda } y) \& \text{NuclWeap}(y)))[\text{token001}]$
3) $\Box((\exists x(A \,\&\, B \,\&\, C \,\&\, D)) \rightarrow \exists x(A \,\&\, D))$
4) $\exists x(\text{AssertionAct}(x) \,\&$
   $\text{PropositionalContent}(x) = (\text{that}(\exists y(\text{Owns}(\text{alQaeda } y) \& \text{NuclWeap}(y)))[\text{token001}]$
5) $\Diamond(\exists y(\text{Owns}(\text{alQaeda } y) \& \text{NuclWeap}(y)))$
6) $\exists y(\text{Owns}(\text{alQaeda } y) \,\&\, \text{NuclWeap}(y))[\text{token001}]$
7) $\Diamond(\forall x(\text{NuclWeap}(x) \rightarrow \text{WMD}(x)) \& \exists y(\text{Owns}(\text{alQaeda } y) \,\&\, \text{NuclWeap}(y)))$
8) $(\forall x(\text{NuclWeap}(x) \rightarrow \text{WMD}(x)) \,\&\, \exists y(\text{Owns}(\text{alQaeda } y) \,\&\, \text{NuclWeap}(y)))[\text{token001}]$
9) $\Box((\forall x(\text{NuclWeap}(x) \rightarrow \text{WMD}(x)) \,\&$
   $\exists y(\text{Owns}(\text{alQaeda } y) \,\&\, \text{WMD}(y))) \rightarrow \exists x(\text{Owns}(\text{alQaeda } x) \,\&\, \text{NuclWeap}(x)))$
10) $\exists x(\text{Owns}(\text{alQaeda } x) \,\&\, \text{NuclWeap}(x))[\text{token001}]$

The query is true and token001 says so!

Discussion

- Our approach focuses on tokens in a formal language
  - Tokens provide ontological and logical foundation for access control and provenance tracking in deductive information systems
- Speech acts provide the justification for individuation of assertions and query responses as linguistic tokens
  - Also enabling the tracking of "hearsay" provenance
- A form of Labeled Deductive System (Gabbay)
  - We are exploring application of these results to our work
- Approach is extensible to access control and provenance of non-linguistic artifacts (e.g. images, video, paper)

Implementation

- In case you're wondering, this actually works!
- Highfleet has implemented a version of this approach
  - Currently limited to atomic sentences
  - Integration with XKS (CL-based) and triple store (RDF-based) products – stay tuned
- Used for provenance tracking in US DoD system
  - Does not (but could) incorporate hearsay tracking

Grab me after the talk and
I'll show you a demo!

Questions?

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