Lecture 26

Logical foundations of computer science

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 - Can automate analysis of the designed procedures

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 - As opposed to finding one protocol (by hand) that satisfies the properties

Outline:

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 - Develop a formal language for modeling the entire system (protocol, adversary, environment) and its evolution

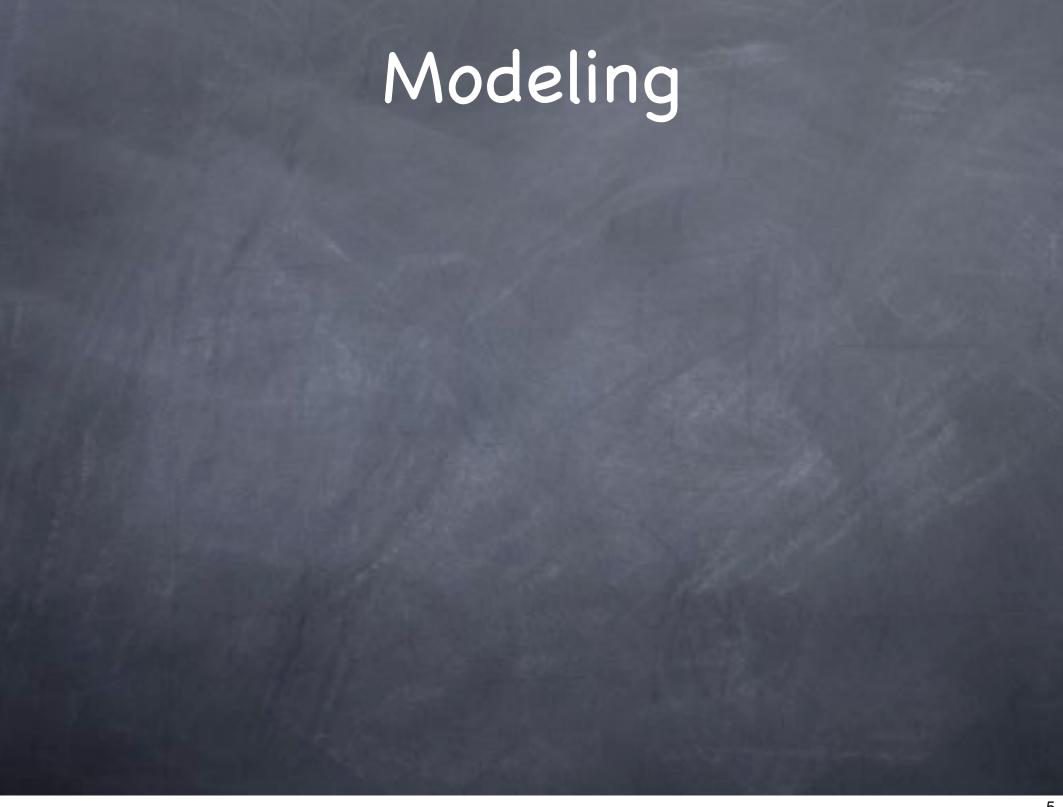
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- Ensure that security/insecurity in the formal model has useful implications in a more realistic model



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 - spi calculus: incorporates an "encryption" primitive into pi calculus which is used to model concurrent, communicating systems

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Modeling

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 - No other rewritings; each party can use terms it received and rewrite them (according to the protocol); adversary can obtain the closure of all terms sent out in the network

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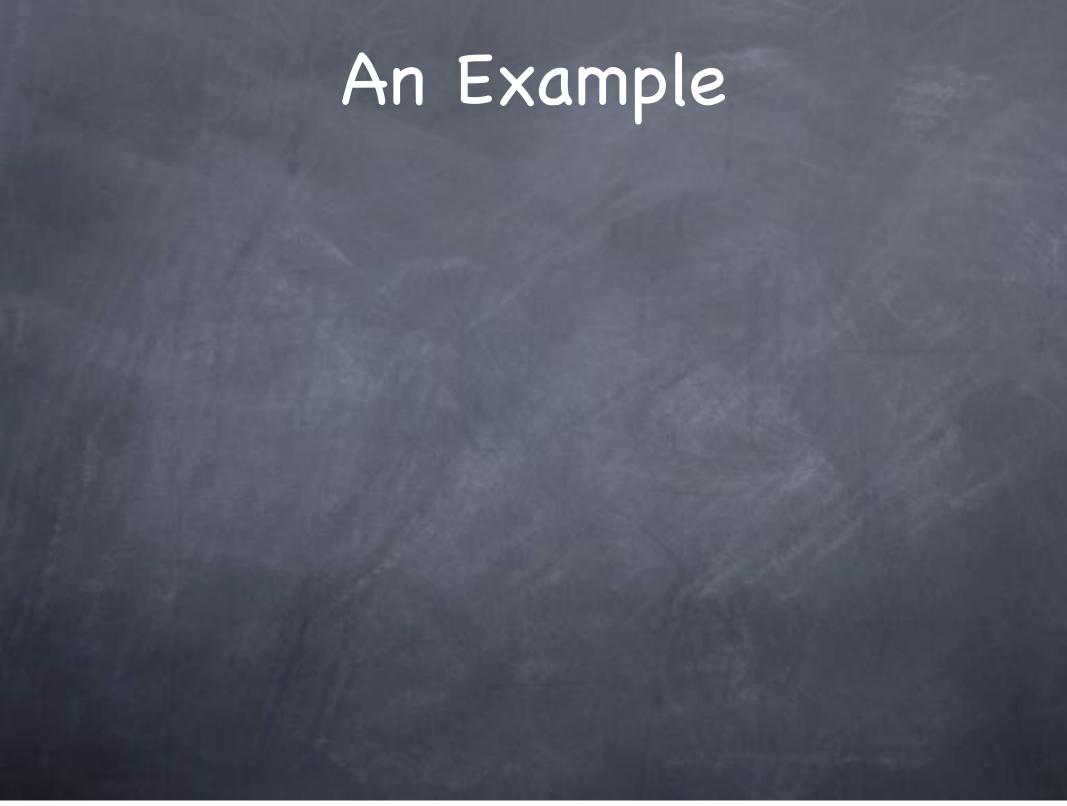
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 (B said X) before that point"

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 - To define security of a protocol, define an ideal protocol (think as ideal functionality, combined with a simulator for the "dummy adversary") and require that the two systems are observationally equivalent
- (But spi calculus incorporates an ideal shared-key encryption and no other cryptographic features; typically limited to secure communication tasks)



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 - Or new bugs in extended settings

```
Responder (M_{resp}):
Initiator (M<sub>init</sub>):
initialize(self, other);
                                                               initialize(self, other);
newrandom(na);
                                                               receive(a_na_enc);
                                                               decrypt(self, a_na_enc, a_na);
pair(self, na, a_na);
encrypt(other, a_na, a_na_enc);
                                                               separate(a_na, a, na);
send(a_na_enc);
                                                               test(a == other);
receive(b_na_nb_enc);
                                                               newrandom(nb);
decrypt(self, b_na_nb_enc, b_na_nb);
                                                               pair(other, na, b_na);
separate(b_na_nb, b, na_nb);
                                                               pair(b_na, nb, b_na_nb);
                                                               encrypt(other, b_na_nb, b_na_nb_enc);
test(b == other);
                                                               send(b_na_nb_enc);
separate(na_nb, na2, nb);
test(na == na2);
                                                               receive(nb_enc);
encrypt(other, nb, nb_enc);
                                                               decrypt(self, nb_enc, nb2);
send(nb_enc);
                                                               test(nb == nb2);
                                                               pair(self, x, b_a_x);
pair(self, other, a_b);
pair(a_b, x, a_b_x);
                                                               pair(Finished, b_a_x, out);
pair(Finished, a_b_x, out);
                                                               output(out);
output(out);
                                                               done;
done;
                  Version 1:
                                        (Initiator's nonce output as secret key)
                               x = na
                  Version 2:
                                        (Responder's nonce output as secret key)
                               x = \mathsf{nb}
```

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- Popular models (Dolev-Yao, BAN logic, spi calculus) have reasonably efficient algorithms for analyzing a variety of security properties, if the system is small (single session)
 - Sometimes state-exploration (using model-checking tools) can be used to discover (some) flaws, but does not prove security

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 - Security against adversaries who use only operations permitted by the formal model

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 - Soundness of the formal model and formal security property for the computational task and primitive used

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 - A somewhat general framework by Backes et al. (CCS 2009)

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 - Promising approach: Universal Composition -- require stronger per-session security that will allow decomposing the analysis to be per-session
 - Only a few security properties have been considered (related to authentication and secure communication). Need to identify automatically verifiable (and sufficient) criteria for each new task

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 - Advantages: 1. Security for concurrent sessions. 2. Easy to use as a sub-module in higher level protocols and analyze security. Analysis of higher level protocols often "automatable"

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- Challenge: Efficient automated analysis in the resulting formal model

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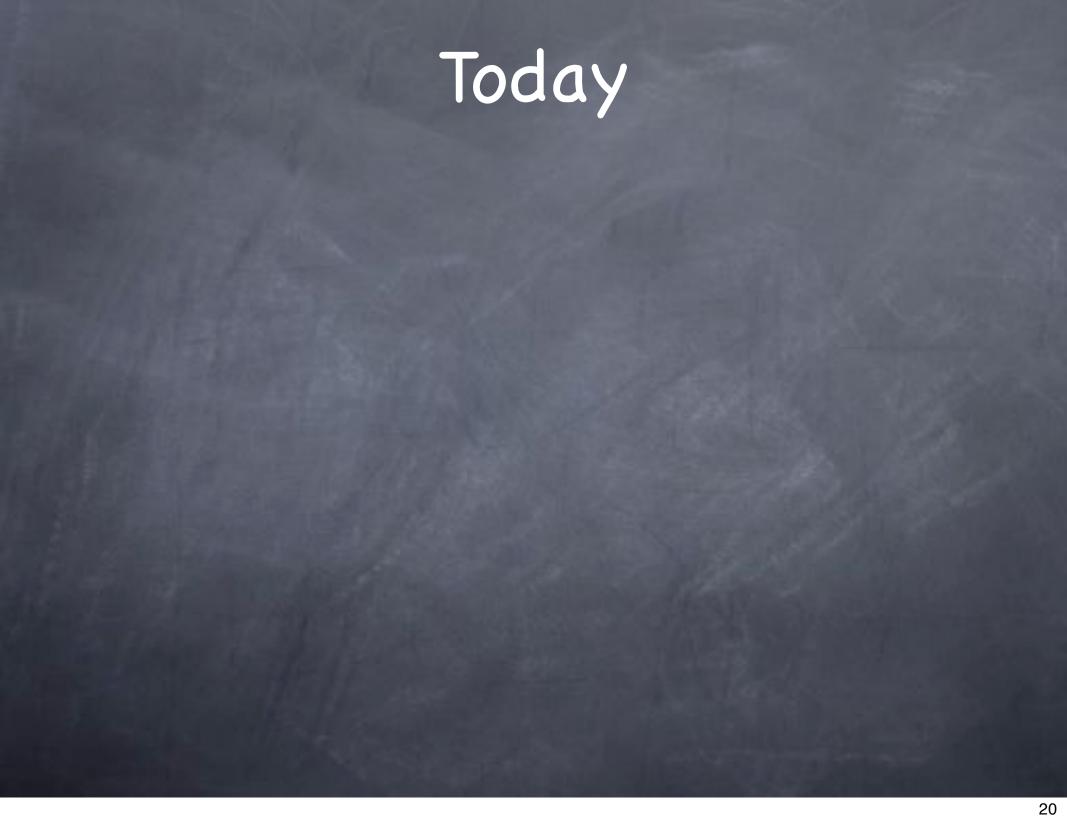
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 - Recent developments in machine verifiable, machineassisted proofs: EasyCrypt/CertiCrypt



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 - Ongoing work: Probabilistic models (e.g. Task PIOA), more tasks, more tools for formal analysis