Security

- What and why?
- Security vs privacy
- How do we know that a protocol is secure? How do we analyse security?
- Does crypto give us security?
    - Software?
    - Key?
    - Protocol?

Crypto basics: symmetric key

- Adityavir (A) and Bhumika (B) have a pre-shared key K. Only they have K
- A encrypts a message M to generate cipher text C using K. We denote this as

$$C = \{M\}_K$$

- B decrypts using K^{-1}

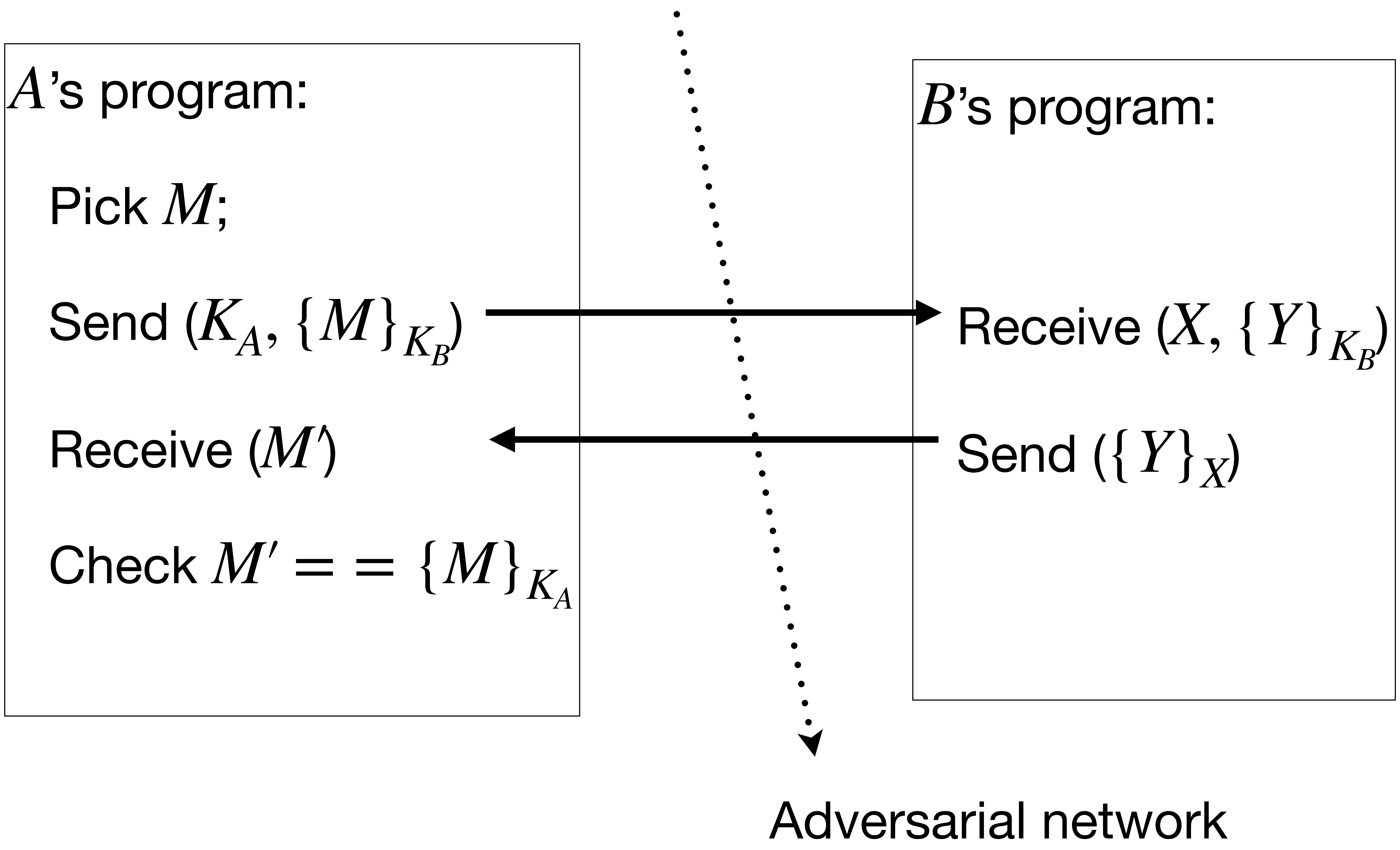
$$M = \{C\}_{K^{-1}}$$

- Example: *Substitution ciphers*. Attacks?

Crypto basic: public key cryptography

- Both A and B have public-secret key pairs (K_A, K_A^{-1}) and (K_B, K_B^{-1})
- K_A and K_B are public information, K_A^{-1} and K_B^{-1} are secret info of A and B
- For both, $C = \{M\}_K \iff M = \{C\}_{K^{-1}}$
- To **encrypt a message** M for B, A sends $C = \{M\}_{K_B}$. Only B can decrypt with $M = \{C\}_{K_B^{-1}}$
- To **sign a message** M, A computes $M' = \{M\}_{K_A^{-1}}$ and sends (M, M'). Anybody can verify $\{M'\}_{K_A} = M$.
- A can combine the above two to send a signed and encrypted message to B (**figure out how and submit by EOD**)

A crypto protocol



Secure?

- **After a valid execution, nobody other than A and B should know M**
- Does the above always hold? Assume the crypto is *bulletproof*
- Suppose Pranit (P) is a ***man in the middle***
- A sends $(K_A, \{M\}_{K_B})$
- P captures and sends $(K_P, \{M\}_{K_B})$ to B
- B sends back $\{M\}_{K_P}$. P captures. Gone!
- P sends back $\{M\}_{K_A}$ to A. *A's check passes.*

Certificate Authorities (CA)

- Of course, without handshaking, S can change the the cipher text $C = \{M\}_{K_B}$ itself to C'. In that case, B would compute $M' = \{C'\}_{K_B^{-1}}$
- A proposed solution is a *trusted third party*, a **CA** (say Suban (S).
- S may issue a certificate to each party
- For example, S may issue to A

$$C(A) = \{A, K_A, R_A, E_A\}_{K_S^{-1}}$$

- R_A and E_A usually are access rights and expiry dates.
- **Assignment:** Figure out what are the trusted third party certificates, and how are they stored on your computer/phone/browser?

The Denning-Sacco disaster (1982?)

- The protocol

$$A \longrightarrow S : A, B$$

$$S \longrightarrow A : C(A), C(B)$$

$$A \longrightarrow B : C(A), C(B), \{\{T_A, K_{AB}\}_{K_A^{-1}}\}_{K_B}$$

- Suppose B wants to masquerade as A to P?

The Denning-Sacco disaster (1982?)

- The protocol

$$A \longrightarrow S : A, B$$

$$S \longrightarrow A : C(A), C(B)$$

$$A \longrightarrow B : C(A), C(B), \{\{T_A, K_{AB}\}_{K_A^{-1}}\}_{K_B}$$

- Suppose B wants to masquerade as A to P?
- B gets from $C(P)$ from S, strips off the outer encryption $\{\ldots\}_{K_B}$ from item 3
- B makes a bogus third message $B \longrightarrow C : C(B), C(C), \{\{T_A, K_{AB}\}_{K_A^{-1}}\}_{K_C}$
- **Solution?**

A session protocol

Symmetric key

$$A \longrightarrow S : \{T_A, B, K_{AB}\}_{K_{AS}}$$

$$S \longrightarrow B : \{T_S, A, K_{AB}\}_{K_{BS}}$$

- K_{AB} is the session key, which may be valid for T_S duration
- Attack?

A session protocol

Symmetric key

$$A \longrightarrow S : \{T_A, B, K_{AB}\}_{K_{AS}}$$

$$S \longrightarrow B : \{T_S, A, K_{AB}\}_{K_{BS}}$$

- K_{AB} is the session key, which may be valid for T_S duration
- Attack?
- C can prolong the session by sending $\{T_S, A, K_{AB}\}_{K_{BS}}$ to S to get back a $\{T'_S, B, K_{AB}\}_{K_{AS}}$, and send that to get back a $\{T''_S, A, K_{AB}\}_{K_{BS}}$
- C can keep the **replay attack** alive till he can steal a key

The perils of challenge-response

- Consider the following protocol for A logging onto B:

$$A \longrightarrow B : A$$

$$B \longrightarrow A : N_B$$ (a random challenge)

$$A \longrightarrow B : \{N_B\}_{K_{AS}}$$

$$B \longrightarrow S : \{A, \{N_B\}_{K_{AS}}\}_{K_{BS}}$$

$$S \longrightarrow B : \{N_B\}_{K_{BS}}$$

The perils of challenge-response

- Consider the following protocol for A logging onto B:

$$A \longrightarrow B : A$$

$$B \longrightarrow A : N_B \text{ (a random challenge)}$$

$$A \longrightarrow B : \{N_B\}_{K_{AS}}$$

$$B \longrightarrow S : \{A, \{N_B\}_{K_{AS}}\}_{K_{BS}}$$

$$S \longrightarrow B : \{N_B\}_{K_{BS}}$$

- . The only connection between the last two exchanges is that one shortly follows the other.

Is this correct?

$A \longrightarrow B : A$

$B \longrightarrow A : N_B$ (a random challenge)

$A \longrightarrow B : \{B, N_B\}_{K_{AS}}$

$B \longrightarrow S : \{A, \{B, N_B\}_{K_{AS}}\}_{K_{BS}}$

$S \longrightarrow B : \{N_B, A\}_{K_{BS}}$

Threat model

- Actors?
- Adversaries?
- Capabilities of adversaries?
- Trust vs verifiability
- Clear articulation of all trust points
- UPI?