Musings on Protocols and Monads

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Abstract

This document captures discussions on formally representing protocols using monadic constructs. This is a living document and will be updated frequently.

Notation

Throughout we use a trivial monadic notation for protocols that serves as our "assembly language" target for protocol compilation. The following conventions hold:

```
do {                % evaluate functions in sequence
     f(x);          % calculate f(x) and discard the result
     y <- f(x);     % calculate f(x) and bind the result to y
     send a $ x;    % evaluate x and send the result to a
     y <- receive a % receive data from a and the result to y
}
```

This is early work, so we play fast and loose with specific syntax and semantics. `send` and `receive` operate synchronously. Each `send` must have a corresponding `receive` to complete its operation.

Example Protocols

Needham-Schroeder-Lowe

Message Sequence

$$A \rightarrow B : \{N_A, A\}_{B^+}$$
$$B \rightarrow A : \{N_A, N_B, B\}_{A^+}$$
$$A \rightarrow B : \{N_B\}_{B^+}$$

Monadic Representation

```
Notes:
-Identifiers "a" and "b" serve as principal identity handles
-na, nb, m1, m2, m3 are variables
-Assume Na and Nb are generated fresh by principals A and B respectively for each run
-Only A can decrypt using a, and B likewise with b
-Public keys are known a priori


Principal A:
do {
     m1 <- encrypt({Na, a}, b);     % encrypt a's nonce and its i.d. with b's public key
     send b $ m1;                   % send result to b
     m2 <- receive b;               % receive (encrypted) message from b
     (na, nb, x) <- decrypt(m2, a); % decrypt m2 using private key of a
     m3 <- encrypt(nb, b);          % encrypt b's nonce with b's public key
     send b $ m3;                   % send result to b
}

Principal B:
do {
     m1 <- receive                  % receive initial (encrypted) message
     (na, a) <- decrypt(m1, b);     % decrypt m1 using b's private key
     m2 <- encrypt({na, Nb, b}, a); % build m2 using na and a
     send a $ m2;                   % send result to a
     m3 <- receive a;               % receive (encrypted) message from b
     (nb) <- decrypt(m3, b);        % decrypt it
}
```


Wide-Mouthed Frog

Message Sequence

$$A \rightarrow S : \{N_A, B, K_{AB}\}_{K_{AS}}$$
$$S \rightarrow B : \{N_S, A, K_{AB}\}_{K_{BS}}$$

Monadic Representation

```
Principal A:
do {
     aCipher <- encrypt({ Na, b, Kab }, Kas);
     send s $ aCipher;
}

Principal S:
do {
     aCihper <- receive a;
     { na, b, kab } <- decrypt(aCipher, Kas);
     kbs <- lookupKey(b);
     sCipher <- encrypt({ Ns, a, kab }, kbs);
     send b $ sCipher;
}

Principal B:
do {
     sCipher <- receive s;
     { ns, a, kab } <- decrypt(sCipher, Kbs);
}
```

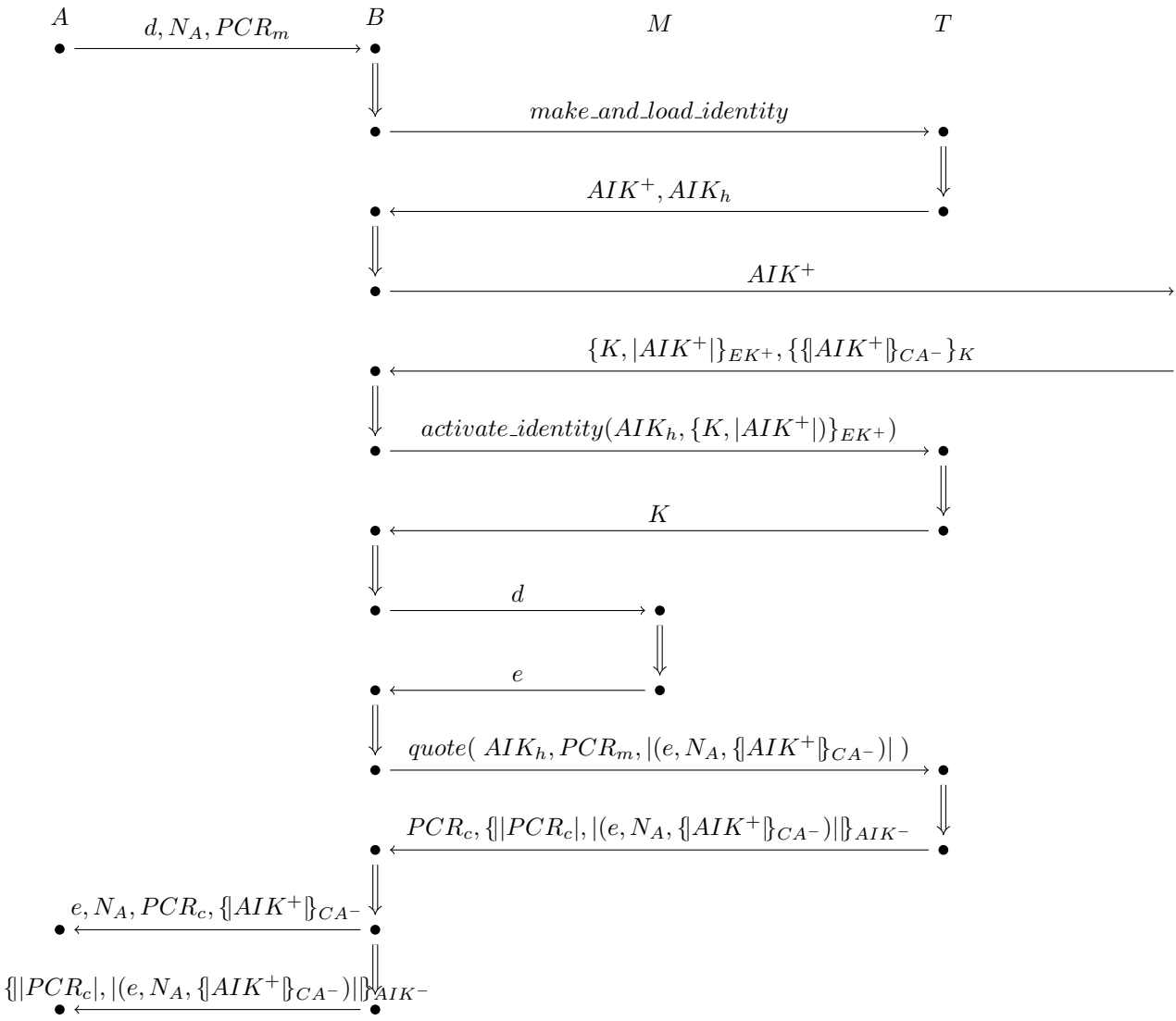
CA Protocol

Message Sequence

$A \rightarrow B : d, N_A, PCR_m$
$B \rightarrow T : make\_and\_load\_identity$
$T \rightarrow B : AIK_h$
$B \rightarrow C : B, AIK^+$
$C \rightarrow B : \{K, |AIK|\}_{EK^+}, \{\{|AIK^+|\}_{CA^-}\}_{K^+}$
$B \rightarrow T : activate\_identity(AIK_h, |AIK|)$
$T \rightarrow B : K$
$B \rightarrow M : d$
$M \rightarrow B : e$
$B \rightarrow T : quote(\ AIK_h, PCR_m, |(e, N_A, \{|AIK^+|\}_{CA^-})|\ )$
$T \rightarrow B : PCR_c, \{||PCR_c|, |(e, N_A, \{|AIK^+|\}_{CA^-})|\}_{AIK^-}$
$B \rightarrow A : e, N_A, PCR_c, \{|AIK^+|\}_{CA^-}$
$B \rightarrow A : \{||PCR_c|, |(e, N_A, \{|AIK^+|\}_{CA^-})|\}_{AIK^-}$

KEY		
A	:	Appraiser
B	:	Attestation Agent
T	:	TPM
C	:	Certificate Authority
M	:	Measurer
d	:	desired evidence
e	:	gathered evidence
N_A	:	nonce
PCR_m	:	pcr mask indicating desired pcr registers
PCR_c	:	pcr composite structure containing select pcr register values
AIK_h	:	AIK key handle(used by TPM to reference loaded keys)
K	:	Session key created by C

Strand Space Diagram



Monadic Representation

```
Appraiser:
do {
     send b $ { d, Na, PCRm } ;    %
     { e, na, pcrc, cacert, sig }  <- receive b;
}

Attester:
do {
     { d, na, pcrm }  <- receive a;
     send t $ { make_and_load_identity };
     { aikpub, aikh } <- receive t;
     send c $ { b, aikpub };
     { ekCipher, kCipher } <- receive c;
     send t $ { activate_identity(aikh, ekCipher) };
     { k } <- receive t;
     cacert <- decrypt(kCipher, k);
     send m $ { d };
     { e } <- receive m;
     send t $ { quote(aikh, pcrm, |e, na, cacert| };
     { pcrc, sig } <- receive t;
     send a $ { e, na, pcrc, cacert, sig };
}

Measurer:
do {
     { d }  <- receive b;
     e <- measure(d);
     send b $ { e };
}

CA:
do {
     { bId, aikpub }  <- receive b;
     ekPub <- lookupEkPub(bId);
     cacert <- sign(aikpub, c);
     ekCipher <- encrypt( { K, |aikpub| }, ekPub );
     kCipher <- encrypt( cacert, K);
     send b $ { ekCipher, kCipher };
}
```