Building on existing security infrastructures

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- Chunhua Chen is currently visiting RHUL.

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Security infrastructures

- In order to use cryptography to protect communications, some kind of security infrastructure needs to be in place.
- In its simplest form, this will just be a means to set up shared secret keys between communicating parties.
- Traditionally, e.g. in banking networks, this can be achieved using one or more Trusted Third Parties (TTPs).
- One type of TTP for this purpose is known as a Key Distribution Centre (KDC).
- A KDC shares a secret key with every party, and these keys can be leveraged (using an appropriate protocol) to set up a secret key between any two parties.

Public Key Infrastructures (PKIs)

- A PKI is another type of security infrastructure, based on digital signatures.
- A Certification Authority (CA) creates digitally signed certificates for user public keys, binding a user name to a public key.

The promise of a universal PKI

- A few years ago, PKI was the subject of huge hype.
- Companies producing PKI products (e.g. CA software) or providing PKI services suddenly (and temporarily!) became hugely valuable.
- In many cases the vision sold as part of this hype was of some kind of universal PKI, whereby every PC in the world would have a public key certificate, which could then be used for a huge range of purposes, e.g.:
  - secure e-commerce;
  - universal secure e-government;
  - secure home banking;
  - electronic signatures for all;
  - …

PKI – what happens in practice I

- Of course, this has not happened.
- There are many PKIs, each set up for a specific purpose.
- For example:
  - companies have their own PKIs, used to support internal secure communications;
  - MasterCard and Visa (and card issuing banks) have PKIs set up to support EMV (used to support smart card based credit/debit card transactions, e.g. in parts of Europe);
  - Internet web sites have certificates used for SSL/TLS security.
- There are, of course, many explanations for this – one being the fact that the policies under which certificates are issued will depend on the context of use.

PKI – what happens in practice II

- More generally, PC users do not have the expertise or motivation to generate a signature key pair, and obtain a certificate for their public key.
- This can be seen from the failure of the SET e-commerce secure payment system, one of the major obstacles to the adoption of which was the need for every user to generate a key pair, and take a copy of their public key to their bank.
- End users cannot be expected to understand the operation of public key cryptography.
- Moreover, current PCs typically do not have a means for secure key storage (needed for the private key).

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Background

- The term *Generic Authentication Architecture* (GAA) has been developed within the mobile phone community.
- It refers to a standardised way of exploiting the mobile phone security infrastructure to provide general purpose authentication and key management services.
- The mobile operator acts as a TTP.
- We start by describing this architecture in general terms.

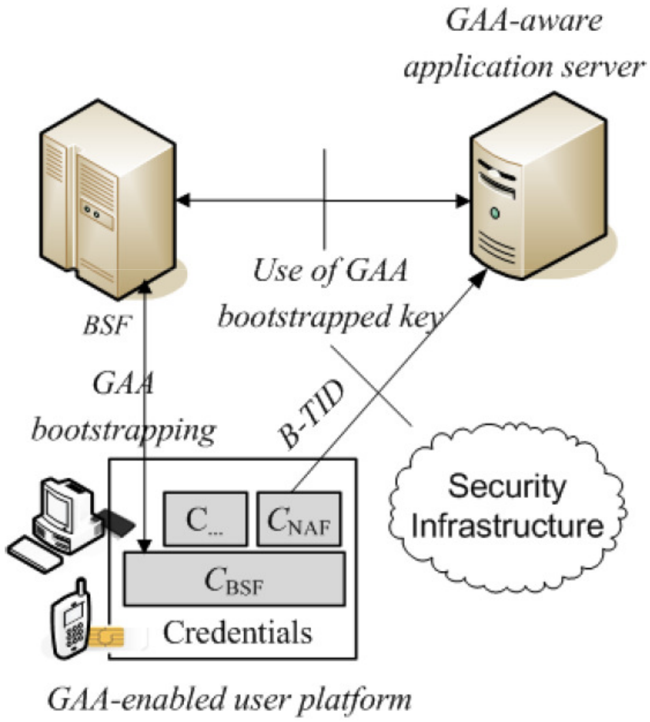
GAA roles

- The GAA architecture involves three roles:
  - **Bootstrapping Server Function (BSF)** – this is the TTP that provides the service;
  - **GAA-aware application server** – has trust relationship with BSF;
  - **GAA-enabled user platform** – has an existing security relationship (e.g. shared secret key) with the BSF.

GAA service

- GAA establishes an authenticated **application- and server**-specific secret key between the GAA-enabled user platform and an arbitrary GAA-aware application server.
- The user must have a mobile phone subscription.
- The target server must have a relationship with the GAA service provider.

GAA overview



GAA procedures

- Two main procedures:
  - **GAA bootstrapping** – Establishes a secret master key *MK* (and an identifier *B-TID* for the key and a key lifetime) between GAA-enabled user platform and the BSF.
  - **Use of bootstrapped keys** – Establishes an application- and server-specific session key *SK* between platform and server using *MK* [*MK* is not divulged to the server]:

    $SK = f(MK, \text{server-ID}, \text{app-ID}, \ldots)$

    where *f* is a key derivation function.

Key provisioning

- The GAA-enabled user device can calculate *SK* for itself.
- The GAA-enabled server is provided with *SK* by the BSF.
- Thus a secure channel between the BSF and the server is required.

Our goal

- GAA was designed specifically for use with the 3G mobile telecoms. security infrastructure (we call this UMTS-GAA).
- We show how to provide GAA-like services with other pre-existing infrastructures.
- As a result, any services built on UMTS-GAA can immediately be migrated to other security infrastructures.

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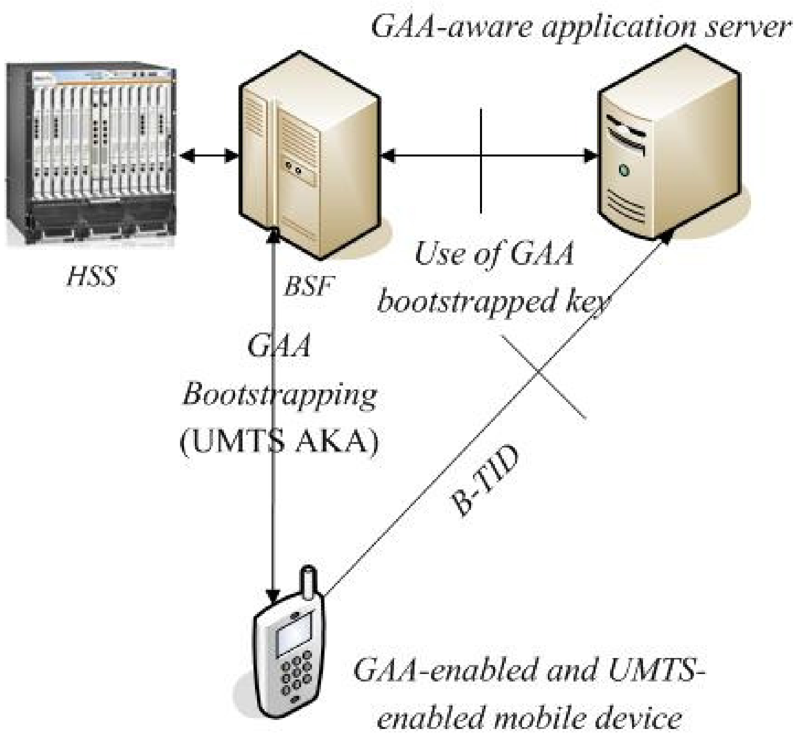
UMTS – background

- The UMTS security infrastructure (supporting mobile phone security) has the following roles:
  - **USIM** – smart card held by user (in phone);
  - **Home Subscriber Server (HSS)** – shares secret key with USIM, and operated by mobile phone service provider with whom user has contractual relationship.

UMTS-GAA

- In UMTS-GAA:
  - GAA-enabled user platform is a UMTS-enabled mobile device, with a USIM;
  - BSF connects to the appropriate HSS for the USIM (may be owned by same operator);
  - UMTS Authentication and Key Agreement protocol (UMTS AKA) is used to establish *MK* between GAA-enabled user platform and BSF (*MK* is concatenation of *IK* and *CK*).

UMTS-GAA



Session key derivation

- In use of bootstrapped keys:

  SK=*f*(*MK*, RAND, mobile-ID, server-ID, app-ID,…)

- RAND is the value used in the UMTS AKA protocol (functions as a random challenge in the protocol).

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TC – a universal security infrastructure?

- Trusted computing provides another security infrastructure.
- Every PC owner will have a crypto-capable PC, with an asymmetric key pair in their TPM and a public key certificate for the public key.
- Moreover, the TPM is capable of generating signature key pairs on demand, of using generated private keys to sign arbitrary data, and of providing secure storage for private keys.

Possible problems

- The key pair provided in every TPM (when shipped to user) is not suitable for use as a general purpose key pair:
  - although it is an RSA key pair, it is intended for use as an encryption/decryption key pair;
  - the TPM does not enable its use for signing arbitrary data.
- The TPM is capable of generating an RSA key pair designed for signing (known as an AIK – Attestation Identity Key), and can also obtain an X.509 certificate for the public part of the AIK from an entity known as a Privacy-CA.
  - However, the private part of the AIK cannot be used to sign arbitrary data.

Solutions to problems

- Get the TPM to generate another signature key pair, and use an AIK to sign a 'certificate' for the public key.
- The private key of this key pair can be used to sign arbitrary data.
- This means that the PC now has a means of generating arbitrary numbers of signature key pairs (essentially automatically) and obtaining certificates for them.
- Only problems are:
  - There is a need to associate two certificates with each key pair (the Privacy-CA certificate for the public AIK, and the AIK-signed certificate for the public key in use);
  - The AIK-signed certificate is not in the standard (X.509) format.

Certificate 'translation'

- A means of addressing these last two problems has been proposed by the TCG.
- Proposed special extension to PKCS#10 (PKCS#10 is a format for submitting certification requests to a CA).
- This extension (SKAE) allows a PC to submit a PC-generated certificate (signed using AIK) for signature public key, with other evidence, as part of a cert request.
- CA verifies the certificate and evidence, and would then generate a new certificate for the PC public key.
- All these processes could be performed by a Java applet, which would give the PC user a secure and automatic means of joining a global PKI.

Example 1 : SSL client side authentication

- Currently, SSL is only used for unilateral authentication i.e. of the server to the client, mainly because client PCs typically do not have key pairs and certificates.
- Precisely the procedure just described could give a means for a PC user to acquire a signature key pair and a public key certificate in order to support SSL client side authentication.
- This is described in greater detail in:
  - A. Alsaid and C. J. Mitchell, 'Preventing phishing attacks using trusted computing technology', in Proc. INC 2006, 6th International Network Conf., Plymouth, July 2006, pp.221-228.
- Related work, including implementations, has been conducted by the OpenTC project.

Example 2: Secure PC-based electronic signatures

- A considerable amount of work has gone into developing legislative and commercial frameworks for electronic signatures.
- However, such frameworks typically require a cumbersome registration procedure for users, and also some means of storing private keys securely.
- The possibility exists that, with the aid of the TPM in a PC, the PC itself can become a trusted platform for the implementation of a personal electronic signature capability, since it can provide the secure storage and also automatically perform the registration procedures.

Portability and privacy issues

- The problem remains that PCs are not typically in one-one correspondence with human users.
- Users have multiple PCs (transferring secrets between TPMs is difficult), and PCs may have multiple users.
- In the latter case. issues may arise in holding a single user accountable for the behaviour of a PC.
- However, TPMs are ‘owned’ by a single user, which typically means that only one individual will be able to use the TPM-protected keys.
- If users want multiple ‘unlinkable’ identities, TPM can generate new key pairs. (Privacy-preserving certification and use of cryptography is key feature of TCG specs.).

Using the TC infrastructure directly

- It is perfectly possible to design applications building directly on the trusted computing infrastructure.
- Substantial literature now exists.
- However, secure application protocols are non-trivial to design.
- Trust relationships can be very unclear.

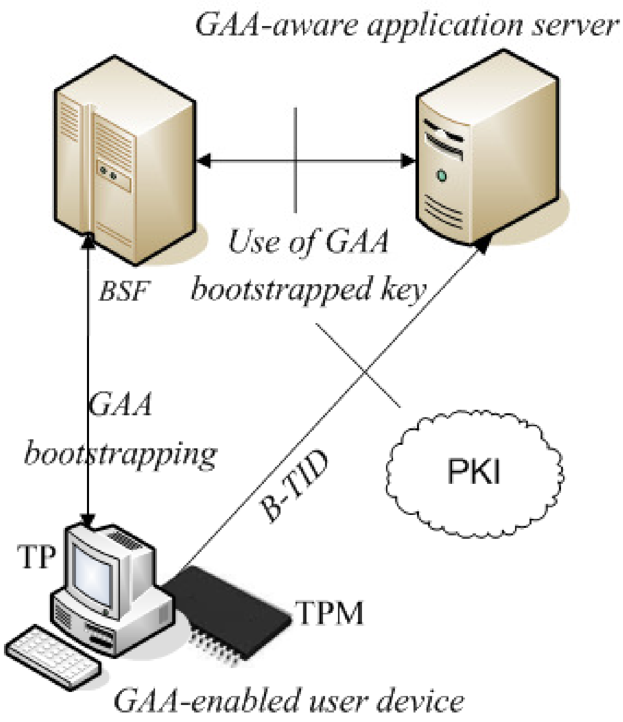
Third party support

- We propose the creation of a GAA-like third party based service to enable the provision of security services building on the TC infrastructure.
- The definition of standard security services, e.g. for key establishment, will enable the TC infrastructure to be exploited in a simple and uniform way.
- It will also provide an opportunity for trusted computing aware third parties to provide novel security services.

Using the GAA architecture

- We have designed a version of GAA (which we call **TC-GAA**) which enables TC to be used to provide generic security services in a simple and uniform way.

TC-GAA



TC-GAA – a sketch

- The TPM on the client machine is instructed to generate a new encryption key pair.
- The public key is then signed (certified) by the TPM using a previously generated Attestation Identity Key (AIK).
- The newly generated certificate is now sent to the BSF along with a previously generated Privacy-CA-generated certificate for the AIK public key.
- After verifying the two certificates, the BSF generates an *MK*, encrypts it using the TPM-generated public key, and ships it back to the TPM.
- This complete the TC-GAA bootstrapping procedure.

TC-GAA properties

- Note that the derivation of *SK* can be very similar to the generic case.
- It is interesting to observe that, unlike UMTS-GAA, the 'issuer' of the TPM is not actively involved.
- Any TTP can function as the BSF without a trust relationship with a further third party.
- This enhances the privacy properties.
- This advantage results from building GAA on asymmetric crypto rather than shared secrets.

GAA as a general framework

- GAA was originally designed to provide a way of exploiting the mobile phone security infrastructure.
- We have shown how it can be used to build on the TC infrastructure.
- Could also be used as a framework for providing general purpose security services building on other pre-existing security infrastructures.

EMV-GAA (sketch)

- A further existing security infrastructure which could be used as the basis of a GAA service is the 'chip and PIN' infrastructure.
- Every EMV card shares a (unique) secret key with the card issuing bank.
- This suggests something very similar to UMTS-GAA could be designed, with the card issuer taking the role of the HSS.
- The user would need a card reader and an appropriate PC application.

EMV-GAA – further developments

- Some EMV cards (supporting CDA or DDA as opposed to the widely used SDA) possess an RSA key pair and a certificate chain for the public key.
- Such a card can be requested to compute a signature by any card reader.
- This could be used to support a more TC-like type of GAA.
- It could also function as the basis of something like a universal PKI.

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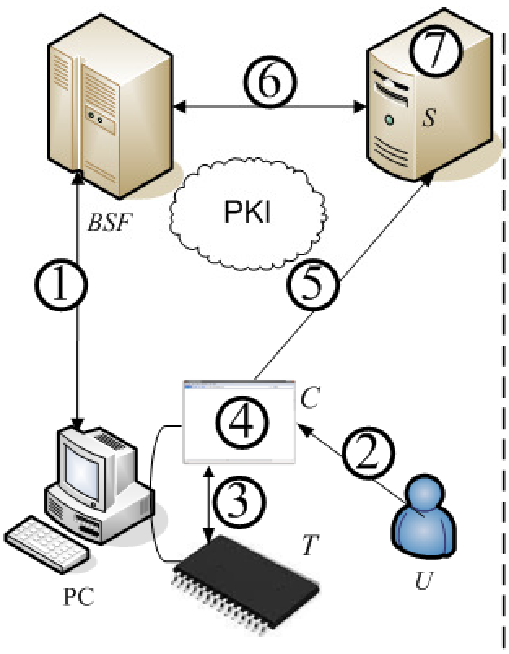
GAA-based one-time passwords I

- We consider one possible application of TC-GAA, namely to enable the simple derivation of one-time passwords (OTPs).
- These passwords are based on a (potentially weak) long-term user password.
- The TC-GAA session key provides protection against brute force password searches.

GAA-based one-time passwords II

- The OTP is computed as a function of the long-term user password and the short term application-specific session key.
- Compromise of the OTP does not enable a brute-force search for the password without knowledge of the session key.
- The TP used in the protocol does not need to be registered to the user – only needs to be trusted not to compromise the password.

TC-GAA-OTP



① *T* ↔ *BSF*: bootstrap GAA credentials.

② *U* → *C*: *username* and *pw*.

③ *C* ↔ *T*: interact for a session key *SK*.

④ *C*: computes *otp* = *f* (*SK*, *pw*).

⑤ *U*(*C*) → *S*: *B-TID*, *username* and *otp*.

⑥ *S* ↔ *BSF*: *S* fecthes *SK* and its lifetime.

⑦ *S* : checks whether or not *SK* is valid;
if so, *S* recomputes *otp* for authentication;
if not, *S* discards the request.

GAA OTP – other instantiations

- The notion of using a GAA session key to help generate an OTP from a long-term weak password applies to all instantiations of GAA.
- Indeed, in parallel work we have designed a series of simple OTP schemes using a GAA-enabled mobile phone.

GAA-based SSO

- We are also developing ways in which GAA could be used to build more general identity management solutions, including single sign-on schemes.
- Some work along these lines has already been standardised for UMTS-GAA, notably interoperation with CardSpace, OpenID and Liberty.

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Building the TC infrastructure

- There is a major problem with rolling out trusted computing applications.
- The envisaged complex infrastructure does not yet exist.
- TC-GAA may help with providing the business case necessary for the emergence of the wide range of third party security services necessary to fully realise the goals of trusted computing.

TPM.next

- The TC-GAA scheme we have proposed is built on the current generation of TPM (v1.2) functionality.
- A new set of TPM specifications (with working name TPM.next) is due to be released shortly.
- Whilst backwards compatible, these allow a richer range of functions, and may make certain tasks simpler.

Trust

- All these GAA-based schemes require some level of trust in the TTP providing the BSF functionality.
- The exact degree of trust depends on the application.
- This may be a problem for some applications, but not for others, particularly for corporate environments.
- In any case, we all depend on TTPs for a variety of aspects of daily life (including banking, telephony, shopping, …).

Questions …