A Lightweight Secure Cyber Foraging Infrastructure for Resource-Constrained Devices

Sachin Goyal and John Carter

School of Computing

University of Utah

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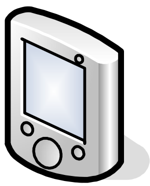
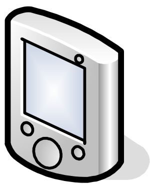
Today's Computing Environments



- **Small, embedded, mobile devices**
- **Ubiquitous network connectivity**

Today's Computing Environments



3GPP
A GLOBAL INITIATIVE

Bluetooth™
Wireless Connections Made Easy

Wi Fi™
The Standard for Wireless Fidelity.

- **Small devices = resource - constrained**
  - **Limited compute power, memory, storage, battery**
- **Can we overcome these resource constraints?**

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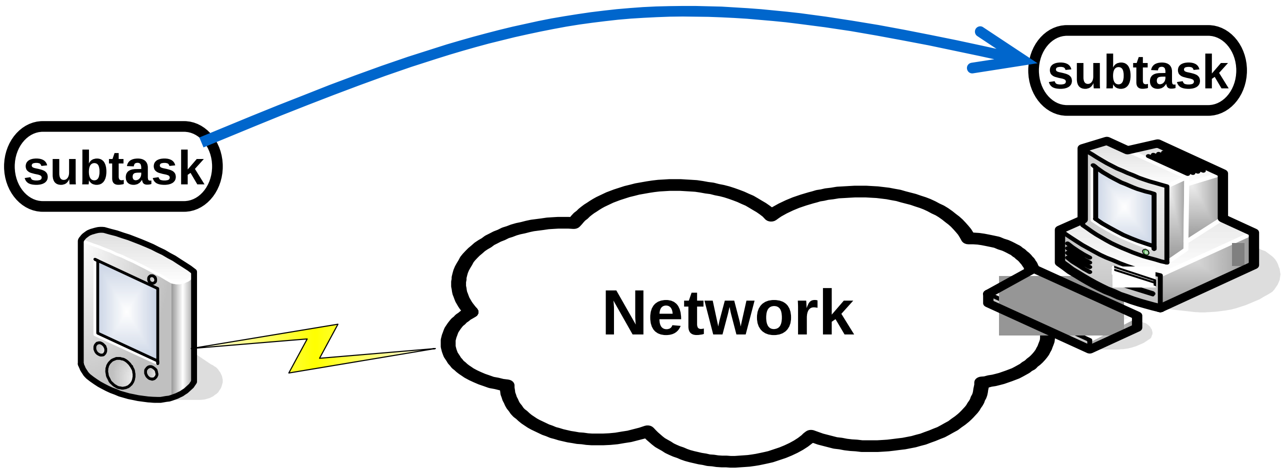
Cyber Foraging or Surrogate Computing



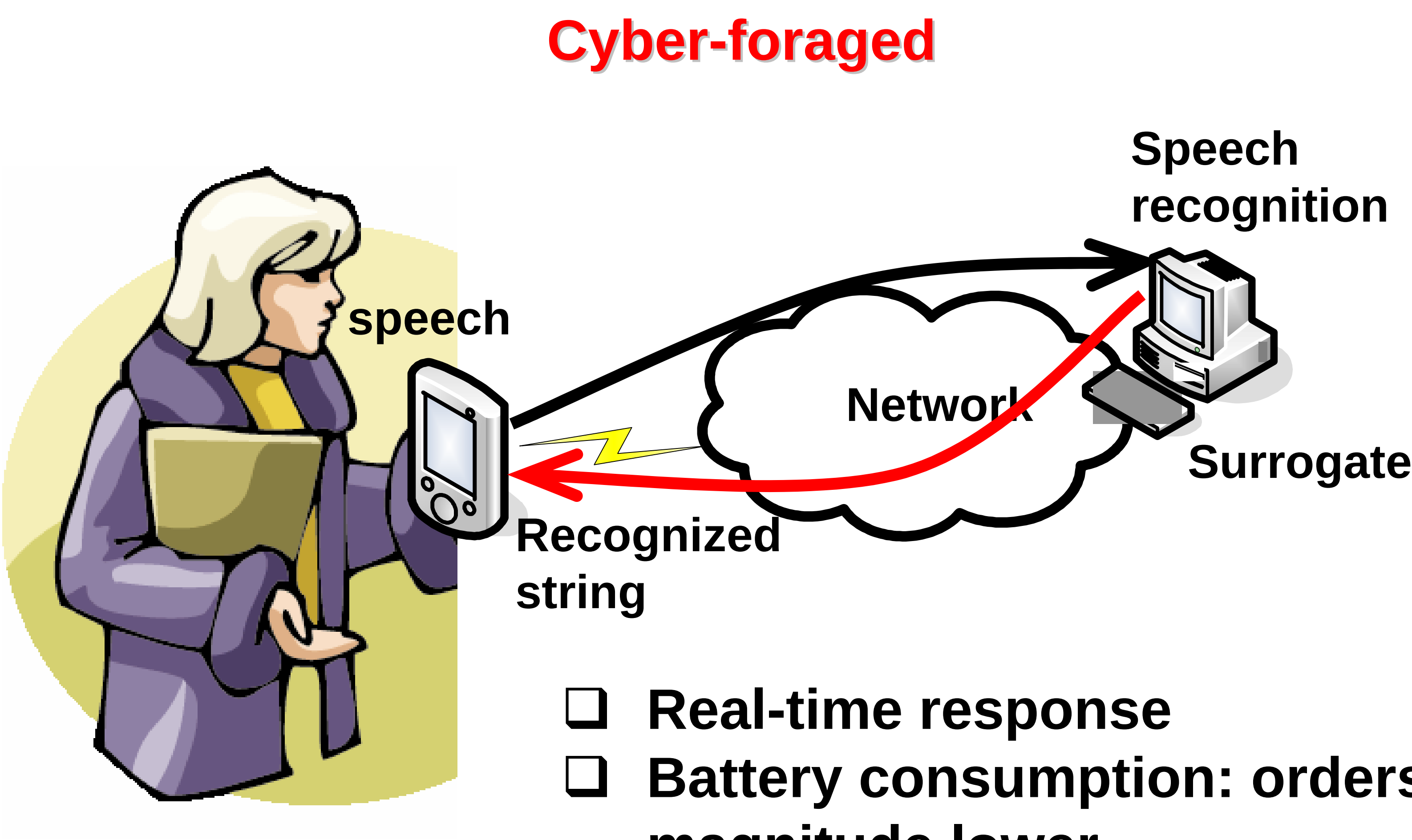
- Enhancing capability of devices with help from powerful computers in environment

Example: Speech Recognition

Local Speech Recognition

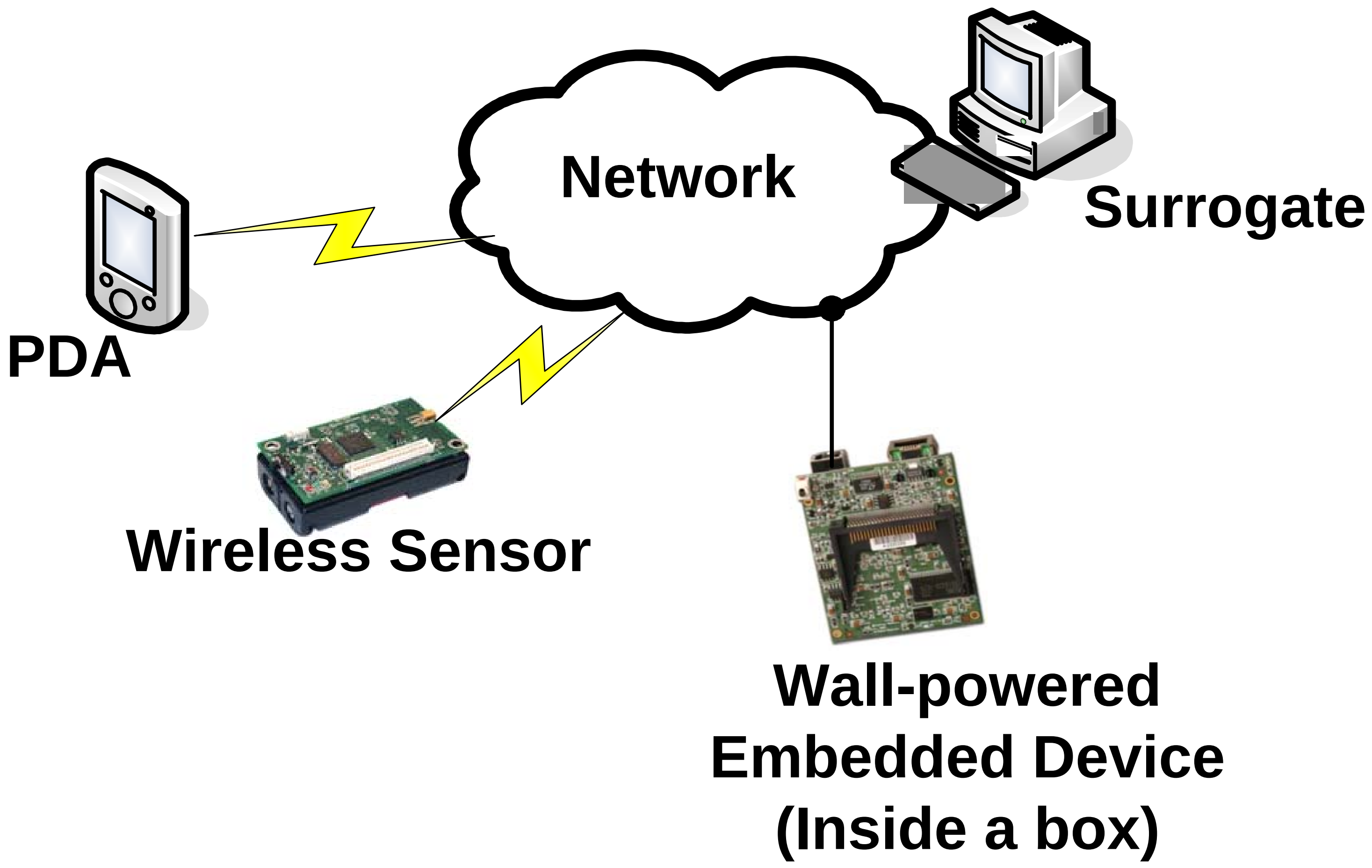
- **Slow response (~minutes)**
- **High battery utilization**

Example: Speech Recognition



- Real-time response
- Battery consumption: orders of magnitude lower

A Smart Home/Office Environment



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This Talk's Focus

- Enable cyber foraging on trusted computers already owned by users
  - Lightweight but flexible infrastructure for clients
  - Surrogate design based on virtual machines
  - Security
  - Surrogate located across Internet (e.g., home PC)

- Speech recognition : 170x improvement in response time, 60x in energy consumption

Related Work

- Spectra / Chroma from CMU
  - Based on Coda
  - Remote data storage + remote execution
- Xenoservers from Cambridge
  - A platform for wide area distributed computing – e.g., utility computing, server on demand
  - Uses virtual machines based on their Xen work

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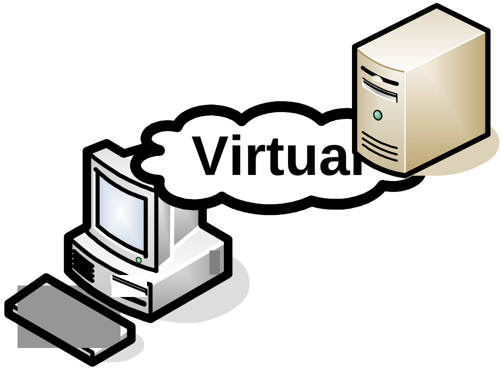
Our Cyber Foraging Infrastructure

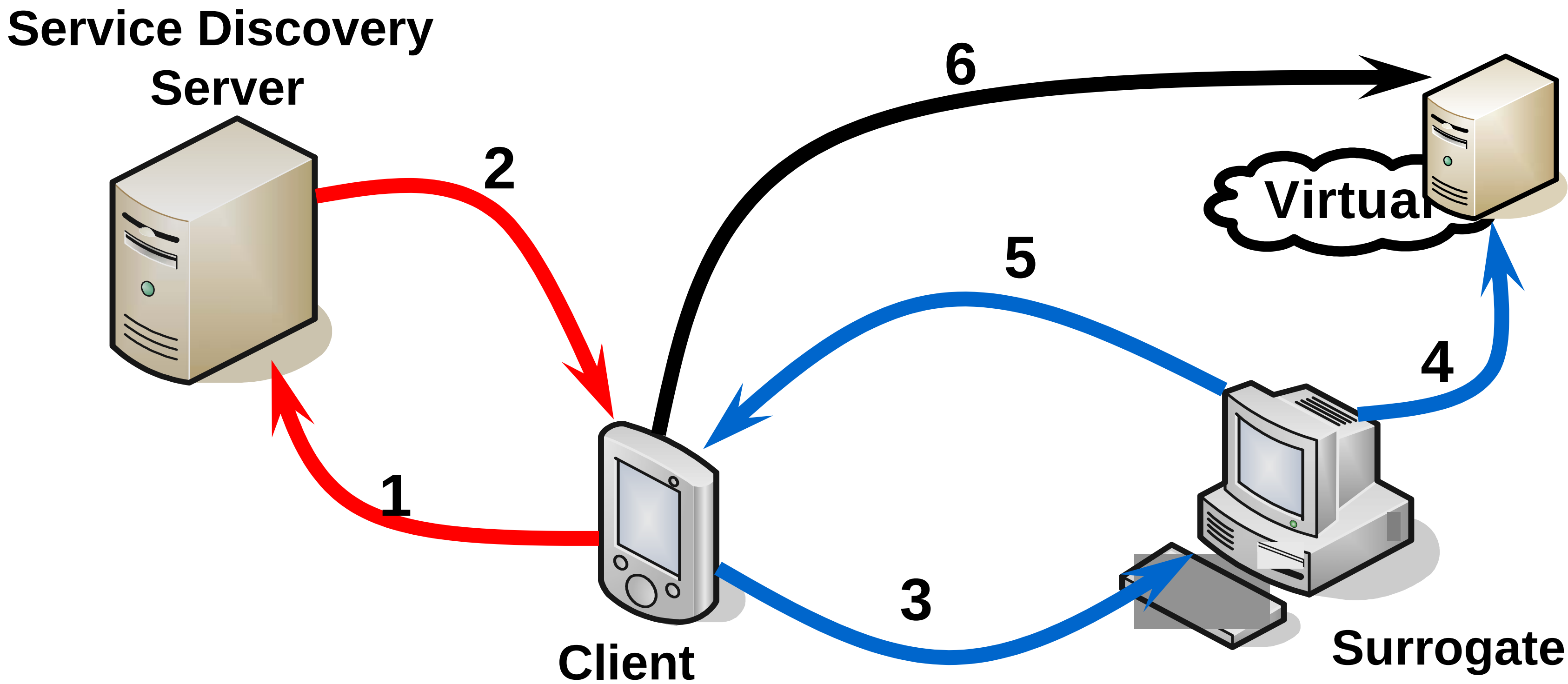
- Lightweight for client – no heavy middleware
- Surrogate: based on virtual machine (VM) technology
  - Isolation
  - Resource control
  - Flexibility
  - Easy cleanup



Our Cyber Foraging Infrastructure

- Two flavors of virtual machines
  - Xen (para-virtualized x86)
  - Linux Vserver: based on encapsulation of processes in groups through a modified kernel
- Client gets complete virtual server
  - Root access
  - Unique IP address
  - Clean disk image of a distribution (e.g. redhat9)

Control Flow



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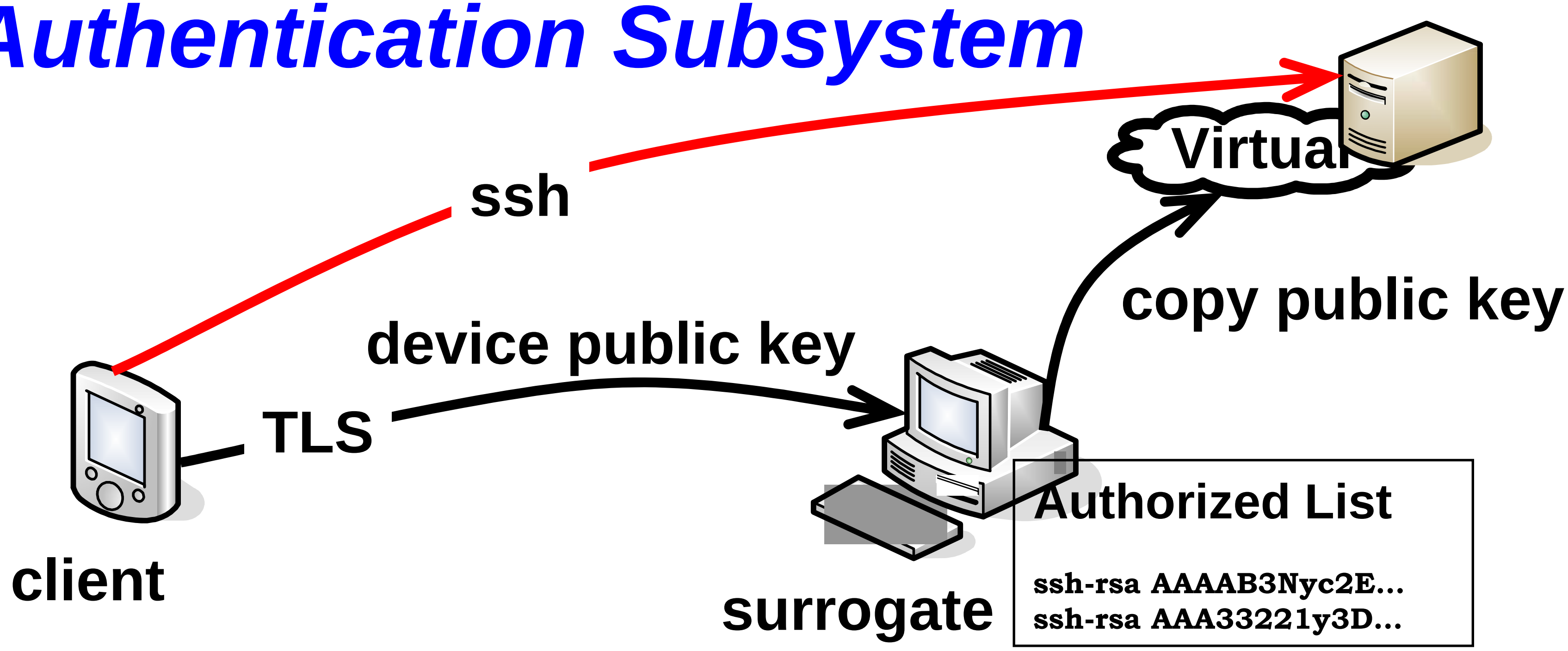
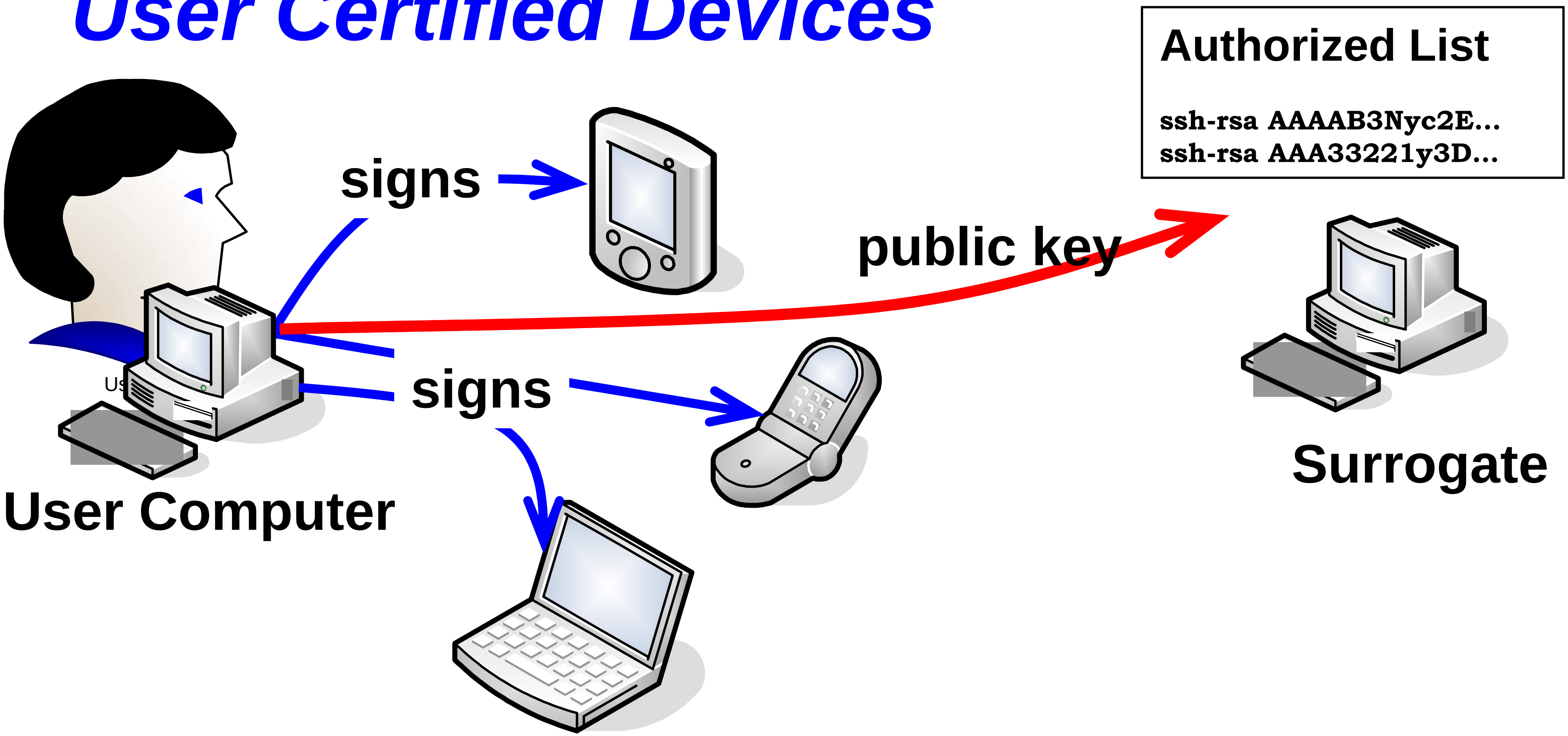
Authentication Subsystem



- If yes, start a virtual server, and copy the key to **/root/.ssh/authorized_keys** file

Result: client can directly ssh to virtual server

User Certified Devices



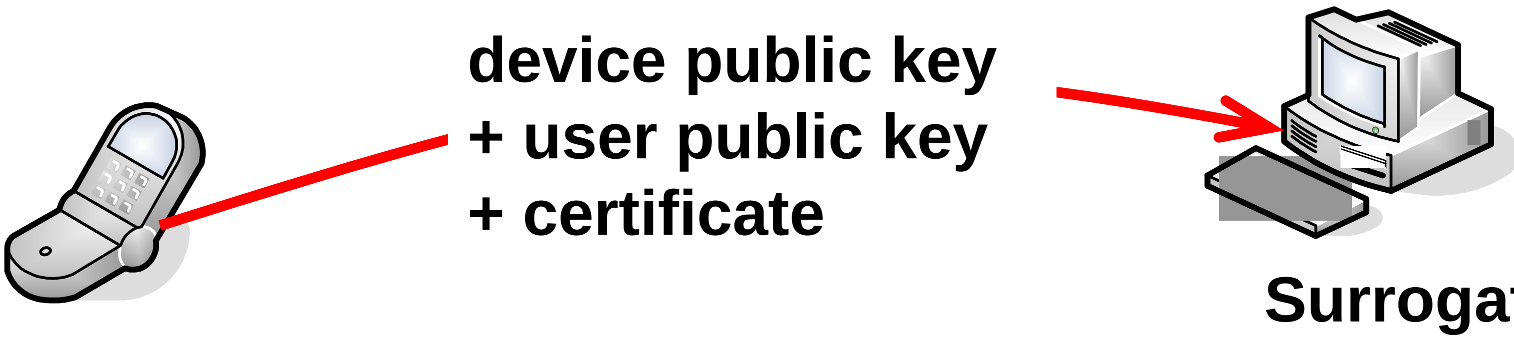
Each Device has their own public-private key.

Now all the devices are authorized to use the surrogate

User Certified Devices

Authorized List

ssh-rsa AAAAB3Nyc2E...
ssh-rsa AAA33221y3D...



Surrogate verifies the certificate and checks if user public key exists in authorized list

Invoking client's task on virtual server

- Client sends script URL through ssh
- Virtual server manager downloads and executes the script
- Script downloads, installs, and runs required programs

Experimental Evaluation

- **Zaurus SL-5500 PDA and Dell 2.4GHz P4 computer with 512 MB of RAM**
- **Two applications**
  - **Sphinx speech recognition from CMU**
  - **Synthetic data mining application**
- **Two networks:**
  - **University of Utah: surrogate on LAN, client connected using 802.11b (2-3 msec RTT)**
  - **Home on broadband Internet: client connected using 802.11b (72-73 msec RTT to surrogate)**

Virtual Server Start and Application Install Experiments

Average response time for allocating and initializing a virtual server

Client location	Linux-Vserver	Xen
Univ	4.22s	12.43s
Home	4.41s	12.57s

Average response time for instantiating the *Sphinx* speech recognition engine

Client location	Linux-Vserver	Xen
Univ	.37s	.30s
Home	.78s	.74s

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Sphinx Speech Recognition

- **Recognition of pre-recorded utterance “Go Forward 10 meters” (44 KB)**

170x **61x**

Type	Client location	Response time	CPU Util	Memory Util	App Size	Battery util
local	-	117.49s	>95%	51.6-55.9%	23MB	1.1%
cyber foraged	University	0.59 -0.69s	0.3-0.5%	1.1%	12KB	.018%
	Home	2.24 -2.31s				.083%

50x **13x**

- **Local – too slow for real time**
- **Cyber foraged: real time as well as low battery utilization (even from home)**

Synthetic Data Mining Benchmark

- **Download three 6.3 MB files, compute MD5 checksum**
- **Client and surrogate on same LAN**

Type	Response time	Battery
Local	61.47s	1.5%
Cyber foraged	2.9s (20x)	0.06% (25x)

- **More improvements possible using network card sleep modes**

Conclusion

- **Describe design and implementation of cyber-foraging system based on virtual machine technology**
- **Great potential to reduce response time and energy consumption**
- **Useful even for surrogate across the Internet**

Future Work

- **Security, trust, and economic models for using surrogates in untrusted environment**
  - **Presenting at WORLDS workshop this Sunday**
- **Service discovery – better requirement matching, load balancing**
- **More applications**
- **Ease of use**

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