The Industrial Challenges in Software and Information Protection

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The 8th International Summer School on Information Security and Protection
July 17- 21, 2017

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Agenda

- **Myself Briefing**
- **Irdeto Overview**
  - Who are we, what do we do, and where we are evolving
- **Part 1: Trends in Security Threats**
- **Part 2: New Challenges and White-box Security**
  - New Challenges to Information Security
  - White-Box Attacks in Real World
  - Software Security: More Than Vulnerability
  - Power of Software Protection
  - Web Application Security Challenges
  - Connected Application central based Security Model
  - Software Security Lifecycle and Digital Asset Protection
  - New View of Information Security and New Research Opportunity
- **Part 3: White-box Security Patterns**
  - Introduction to WB Computing Security Patterns
  - WB Computing Security Pattern Description in Details
- **Summary**

Myself Briefing

- 1975 -1988: Professor of Northwest University in China
- 1988 -1990: Visiting professor of McGill University, Canada
- 1990 -1997: Senior scientist and architect at Nortel
  - 1993: Effective Immune Software (EIS, early Cloakware idea)
- 1997 - 2007: Co-founder and executive positions of Cloakware
- 2007 - present: Chief Architect, Irdeto Canada,
  - leading security research and collaboration with universities worldwide
- 2011 - present: Guest professor of Northwest University, China

Where is Irdeto Canada

Intro to Irdeto

Who are we?

What do we do?

Where we are evolving?

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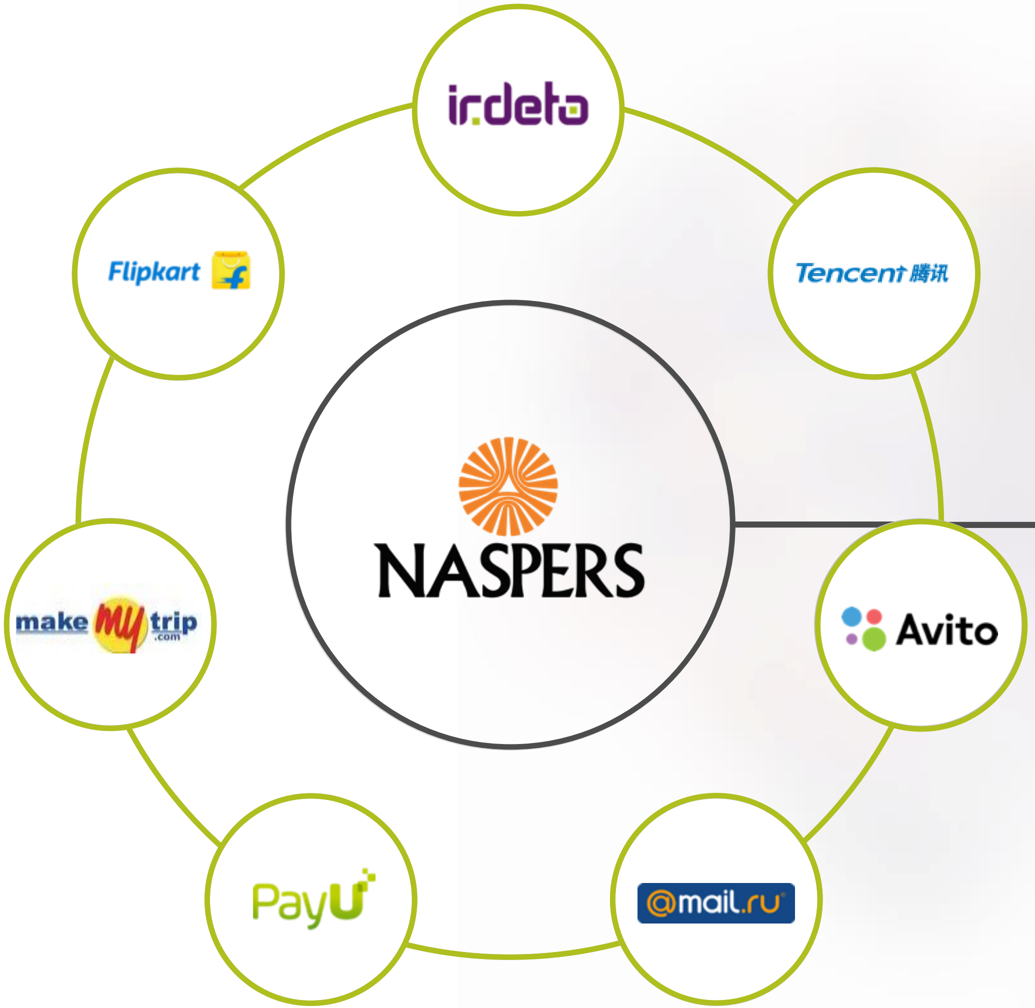


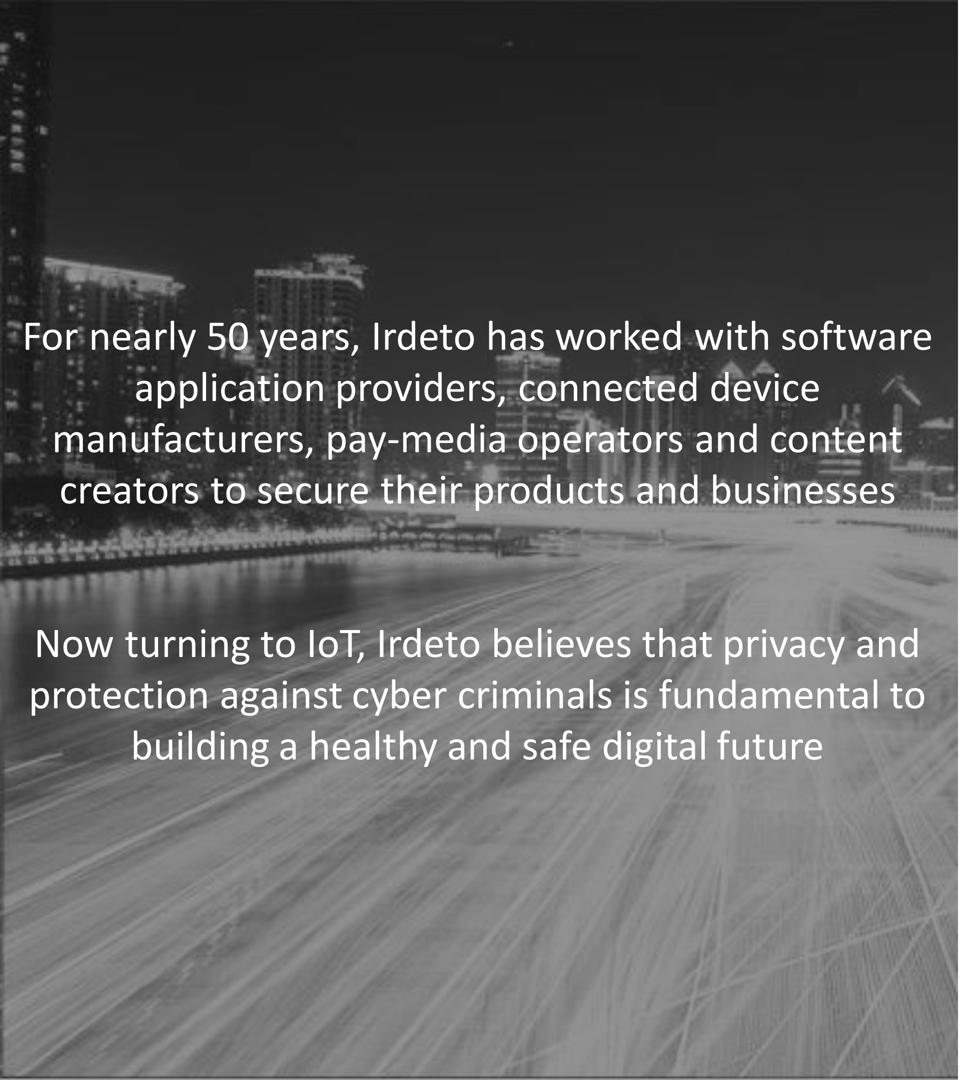
Irdeto is part of the Naspers Group (NPN.SJ)

Naspers is one of the world's largest technology investors

Revenue	**Profit**
US$ 12.2bn	US$ 1.2bn
+22% YoY	+49% YoY
(+6%)	(+21%)

Irdeto is the cybersecurity unit of the Naspers group

Cloakware is the software security brand for Irdeto's IoT offerings



For nearly 50 years, Irdeto has worked with software application providers, connected device manufacturers, pay-media operators and content creators to secure their products and businesses

Now turning to IoT, Irdeto believes that privacy and protection against cyber criminals is fundamental to building a healthy and safe digital future

#1 in software security in pay media

+5 billion devices & applications secured

+191 million cryptographic keys generated and under management

Serving 350 clients worldwide

571 patents & 522 patents pending

+1000 security expert employees

20 locations covering 6 continents

Part 1: **Hacker Trends**

Days of hacking games and movies are over…

... Attacking busines is the new trend!

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“As the chairman pointed out, there are now computers in everything. But I want to suggest another way of thinking about it in that everything is now a computer: This is not a phone. It’s a computer that makes phone calls. A refrigerator is a computer that keeps things cold. ATM machine is a computer with money inside. Your car is not a mechanical device with a computer. It’s a computer with four wheels and an engine… And this is the Internet of Things, and this is what caused the DDoS attack we’re talking about.”

– Bruce Schneier

Speaking before Members of US Congress
Nov 2017

Smart Everything: Can Secure Everything?

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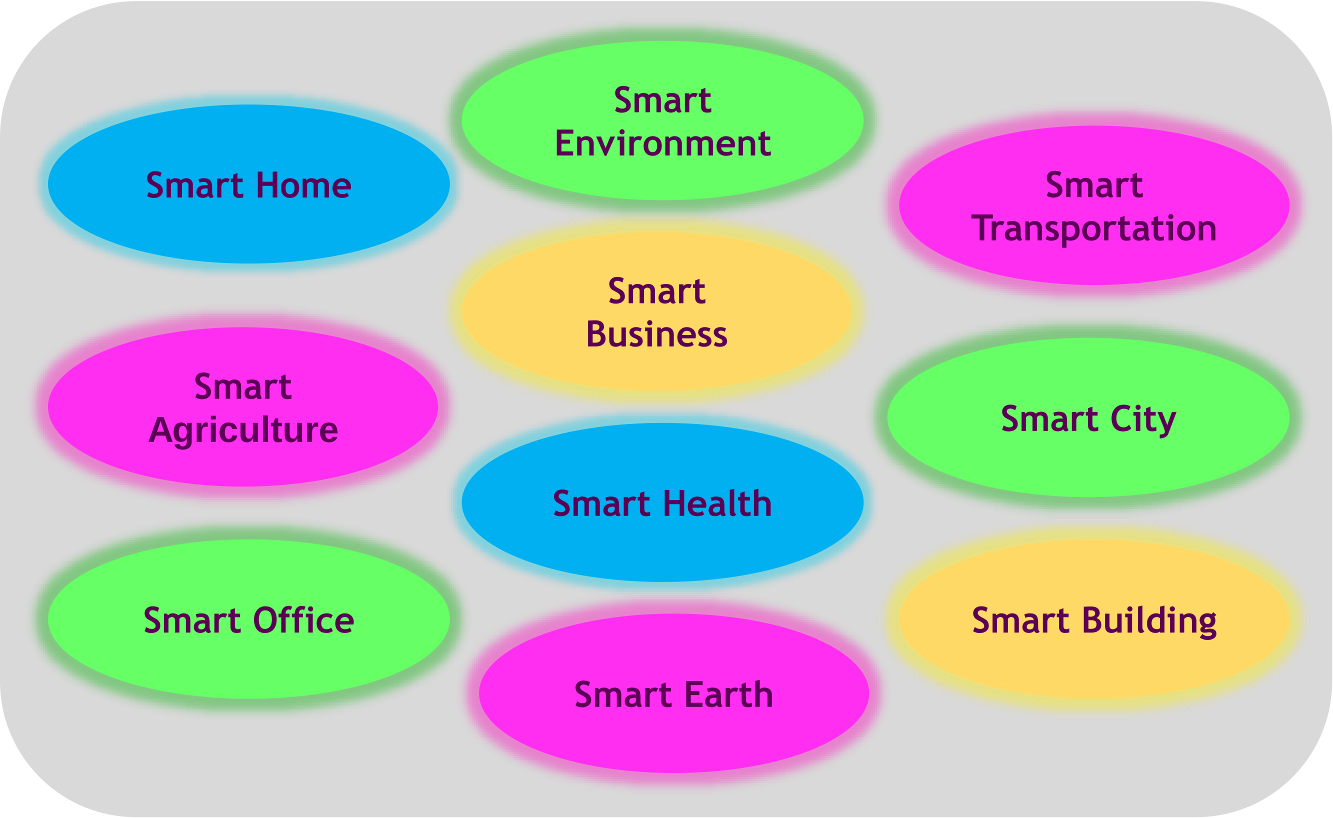
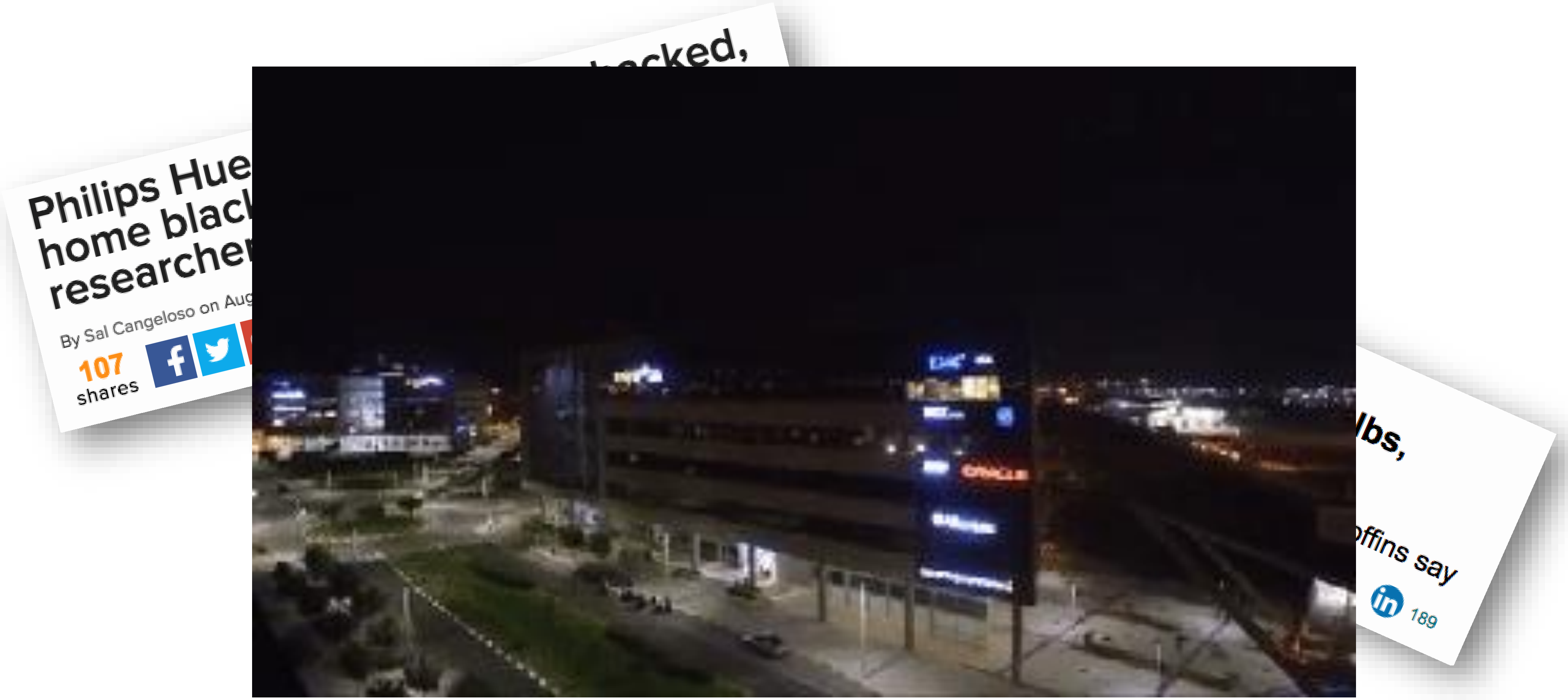



Stranger hacks family's baby monitor and talks to child at night
By CHANTE OWENS November 3, 2016
SOURCE: Z-Wave Alliance
Z-WAVE ALLIANCE
November 17, 2016 09:00 ET
Z-Wave Alliance Announces New Security Requirements for All Z-Wave Certified IoT Devices
The Alliance Board of Directors has voted to mandate all devices receiving Z-Wave Certification after April 2nd, 2017 to include new advanced Security 2 (S2) framework
IoT security camera inf
seconds of plugging it
It took a mere minute and a half for an in
with malware.
Network World | Nov 20, 2016 9:06 AM PT
devices at DEF CON
The results from this year's IoT hacking contest are in and it's not a pretty picture

Philips Hue – Malware



Automotive – Becoming a Favorite Target

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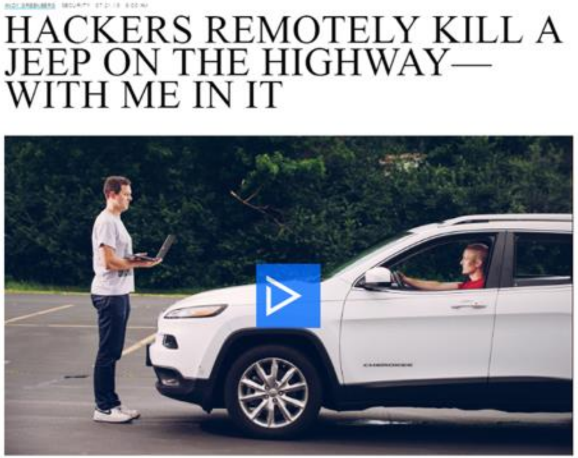
- Local attacks
- Remote attacks
- Personal Data Theft
- Software bugs
- Architectural defects



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Automotive Cybersecurity History

2010
Wifi laptop remote control

2010
OnStar remote control

2014
Remote control through Zubie dongle

2015
Dealer malware propagation

2015
BMW unlock

2015
OnStar unlock / start takeover

2015
Key fob replicator

2015
Jeep hack

2015
Tesla WebKit hack

2015
Corvette insurance dongle

2016
Nissan Leaf mobile app

2016
Tesla Wifi and Android App

Cybercrime has evolved from single hackers into resilient highly skilled organizations performing global cyber attacks

- *38.5% of firms have experienced a cyber attack in the past 12 months*
- *21% of these attacks had a cost higher than 5 million EUR*

(Source: Marsh report September 2016)

Ransomware – Willingness To Harm


Healthcare IT News
TOPICS SIGN UP MAIN MENU

Privacy & Security

Ransomware attackers collect ransom from Kansas hospital, don't unlock all the data, then demand more money

Kansas Heart Hospital declined to pay the second ransom, saying that would not be wise. Security experts, meanwhile, are warning that ransomware attacks will only get worse.

By Bill Siwicki | May 23, 2016 | 02:58 PM

SHARE 823

Mobile ransomware quadrupled in 2015

Fast becoming a mature, million dollar business for organized crime

35 known ransomware “products” in operation in 2015

Targeting corporations and public entities such as municipal gov’ts and hospitals

Ransomware in Healthcare

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2016
Klinikum Arnsberg
Germany

2016
Methodist Hospital
USA

Healthcare providers pay USD $6B annually to ransomware

2016
Hollywood
Presbyterian
USA

USA top target for ransomware with 320,000+ infected systems

2016
Lukas Hospital
Germany

2016
Chino Valley Medical
USA

TeslaCrypt | 777
Xorist | Cerber
GhostCrypt | SamSam
CryptoLocker
MSIL/Samas | Locky

2016
Kansas Heart Hospital
USA

Cerber “ransomware-as-a-service” takes 40% of extorted profits; run by Russian crime ring

2016
DeKalb Health
USA

2016
Ottawa Hospital
Canada

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- On May 12, 2017: WannaCry attacks to 300,000 machines in 150 countries worldwide
- On June 27, 2017: Petya attacks in Europe, the Middle East and the US

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KrebsOnSecurity.com was knocked offline by 620Gbps DDos. One of the biggest ever recorded. This was followed by a 1Tbps attack against French web host OVH

Indications are that an estimated 500k+ IoT devices such as security cameras and DVRs were used as a botnet for the attack.

Botnet of refrigerators? Cars? Traffic Lights? Medical Devices?

Would we even know it was happening?

Increased Connectivity means Increased Risk – and Different Attack Type

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TRENDS

- Open systems, open source
- More third party applications, developer tools
- Regulatory compliance and third party licenses
- High value assets are now "connected"
- More applications, more access and private user data

RISKS

- More attack vectors
- Increased attacker incentives
- Greater Insider threat
- Device revocation
- Automated attacks

EXPOSURE

- ✓ Slower market adoption
- ✓ Financial loss
- ✓ Brand erosion
- ✓ Lost shareholder value

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Problem: All software is vulnerable

- Advances in debugging and reverse engineering techniques have empowered increasingly more capable and tech-savvy hackers
- Unsecured software is as readable as a book – IP and critical algorithms are simple for hackers to access and exploit
- Open source software and hacker collaboration compound the problem, providing “easy learning”
- Hacking is a business - Hackers make their profit by scaling and selling modified versions of applications

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- Challenges to design a secure system
  - The system should be secure but ….
    - Be usable and easy for users
    - Be within the computational, memory and power consumption budget of a device
    - Have a lifecycle – be manufactured, distributed, used and end of life
    - Be cost effective – cost significantly less than the asset to be protected
    - Fulfill time to market requirements
  - Remain secure over the life cycle of the system

Economics of Security (2/2)

- Challenges to an attacker
  - Find a single point of failure of security
  - Cost of finding and reproducing attack should be much less than the reward
  - Depending on attack – reward ranges from sense of achievement to billions of dollars
- The attacker's job is often much easier than the designer's
  - The designer needs to make a complex system work all the time without any point of failure
  - The attacker just needs to find a single flaw as a start

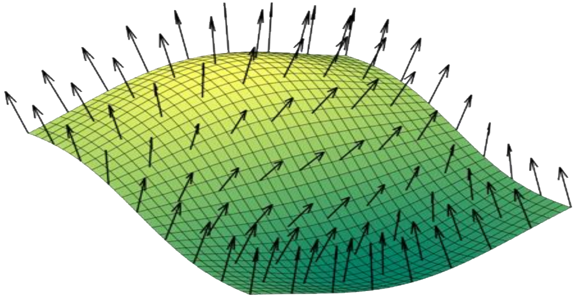
Vulnerability Does Always Exist

- Vulnerability

  A weakness which allows an attacker to develop and launch an attack

- Vulnerability can be introduced by different development stages of a computer system
  - Requirements flaws
  - Design and architecture flaws
  - Infrastructure flaws
  - Implementation flaws
  - Integration flaws
  - Deployment flaws

- **Attack Surface**
  The sum of the different points where an attacker can break a system



- **Zero Day Vulnerability and Attack**
  Un-exploited and un-known security holes to vendors that can be developed into brand new attacks

- A security vulnerability is the intersection of three elements:
  - A system susceptibility or flaw
  - An attacker has access to the flaw
  - An attackers capability to exploit the flaw

Security Debt

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- Architecture Debt
  - Poor security architecture
- Design Debt
  - Poor security design decision
- Implementation Debt
  - Poor implementation including bad coding
- Test Debt
  - Lack enough security testing and security assurance

Planning an Attack on an IoT Target

- Attack Points:
  - Device (Receives the most focus)
  - Smartphone app
  - Communications and connection points
  - Other things the device connects to, like your router, your network, etc
  - Cloud (via the Internet)

- Phases of an attack
  - Investigation
  - Leverage a weakness
  - Peel the onion
  - Rinse and repeat
  - Launch an attack

Part 2: **New Challenges and White-box Security**

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New Challenges to Information Security

Technologic Impacts to Modern Business Model

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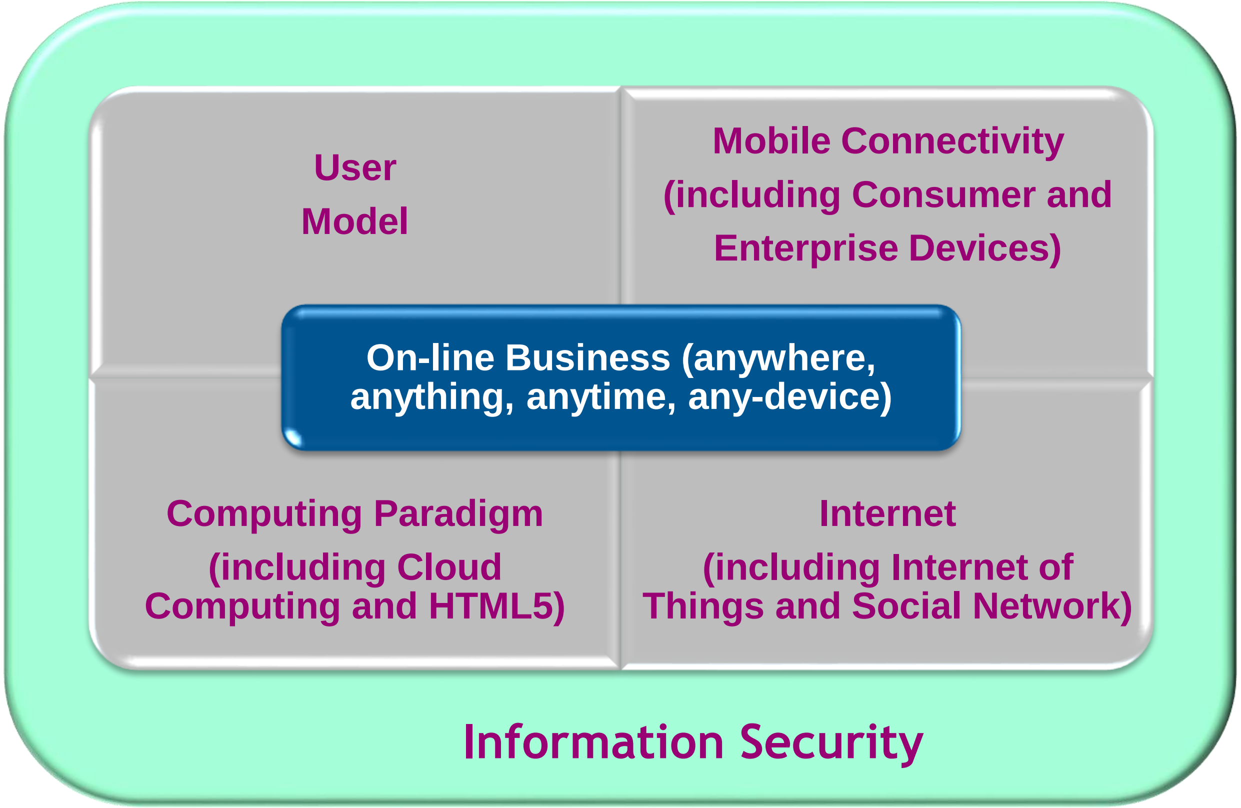

User Model Evolution

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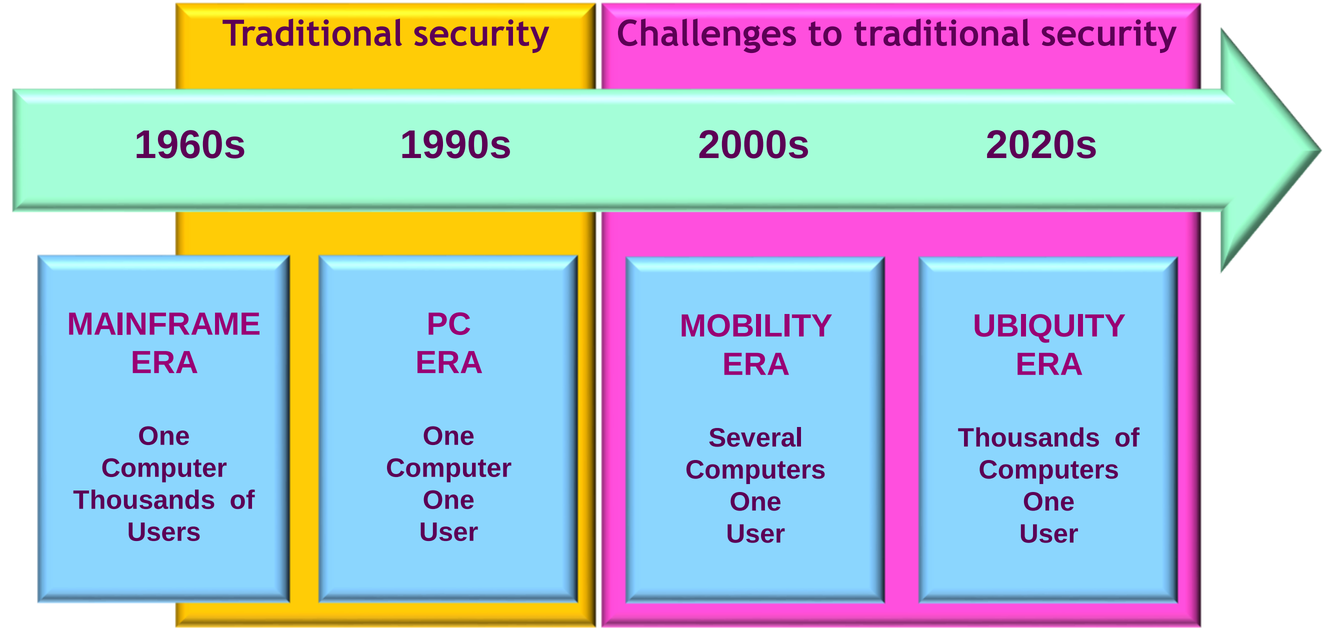
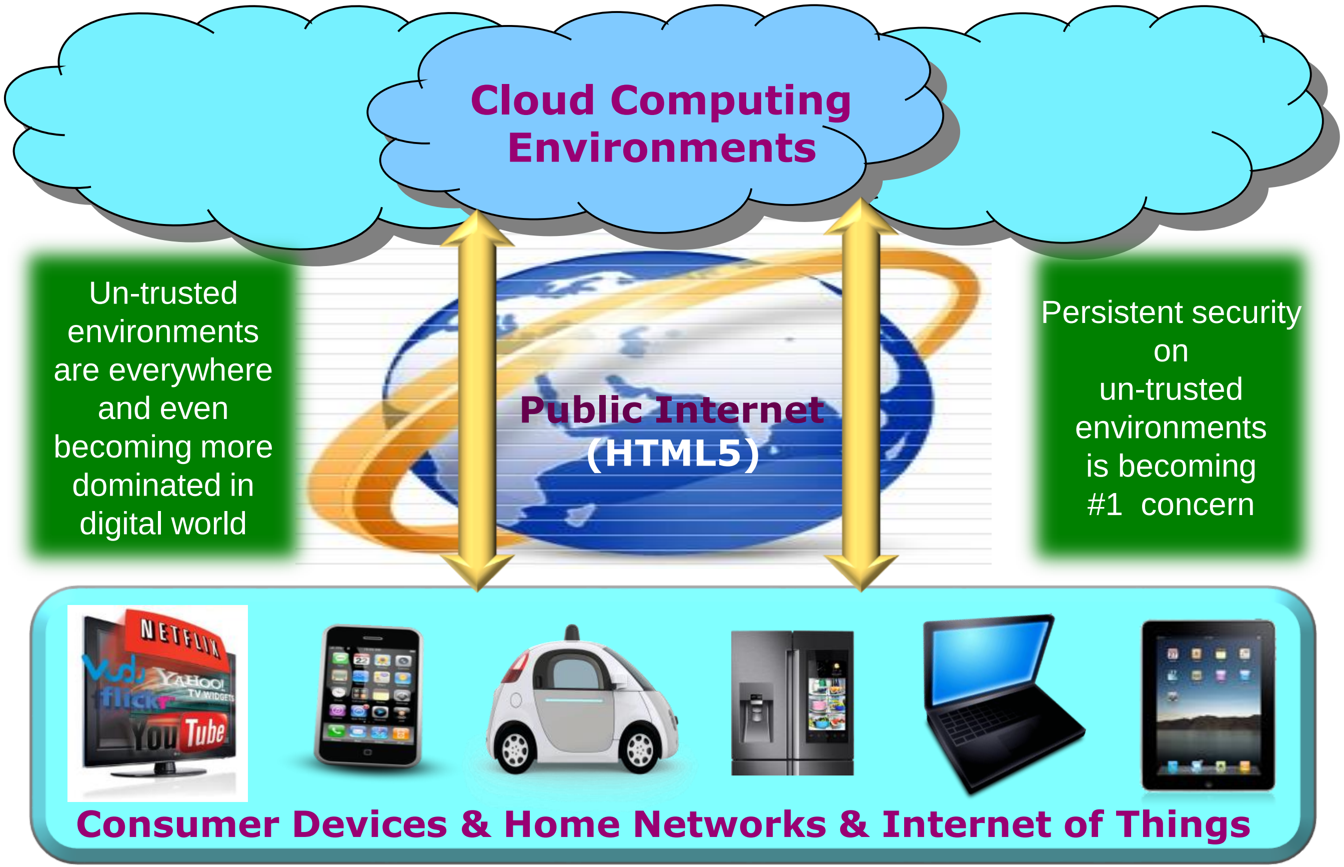


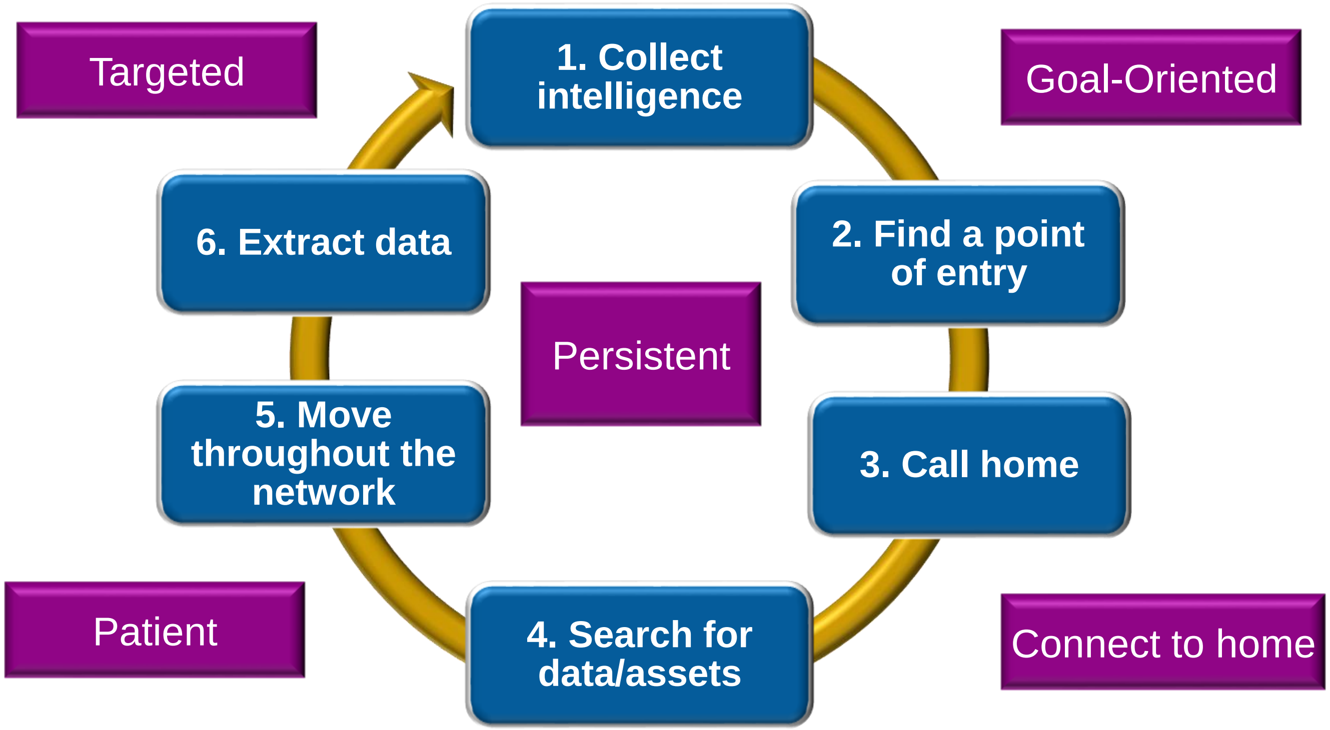
As digital technologies become universal, they have transformed the people living and life, and business environment.

Un-Trusted Environment Reality



Advanced Persistent Threats (APT or APA)

You are compromised! But you just don't know it!!



Insider Threats - No longer an Incident, It's a Big Problem

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- Two categories of insider tcareless userhreats (ITS)
  - By [ex-]employees or associates of an organization who either maliciously or accidentally take action that put their organizations and data at risk.
  - By outsiders who have obtained the legitimate credentials needed to gain access and conduct malicious activities that cause operational harm and steal data using APT.
- Insider threats landscape (2017 report)
  - Top insider threats
    - Inadvertent data breaches (careless user): 71%
    - Negligent data breaches (user willfully ignoring policy): 68%
    - Malicious data breaches (user willfully causing harm): 61%
  - Data most vulnerable to insider attacks
    - Customer data: 63%
    - Financial data: 55%
    - Intellectual property: 54%

The huge amount of data residing on servers (clouds) is a highly attractive target

- Black-box context is facing new security problems that traditional security models and technologies cannot not offer sufficient solution.
- **There is no system can be fully trusted and secured.**

Traditional Security: Seriously Broken (1/3)

Traditional security is not designed to counter today's new and advanced threats. Why?

- Sandboxing-based
  - One of oldest security techniques and has been widely using to prevent traditional man-in-the-middle attacks not man-at-the end attacks.
  - It seeks to protect the host against hostile software, not the SW systems or applications and their data against the potentially hostile host
  - It leaves us with a false sense of security: many threats cannot be addressed by the approach. For example, it does absolutely nothing to prevent massive surveillance.

- Signature-based
  - The long-standing blacklisting approach is losing the battle against new malware.
  - Right now, about more about 1 million new pieces of malware every day, and this will get much worse in the future.
  - Signature-based defenses are grossly insufficient.

Traditional Security: Seriously Broken (2/3)

- Perimeter Oriented
  - Perimeter oriented approaches concentrate on preventing or detecting threats entering networks of an organization, but perimeters are very porous these days.
  - Anything with an IP address can be a launch pad for attackers
  - Perimeter tools and security techniques were not designed to protect the data and against today's advanced threats.
  - Within the perimeter, old security models are reactive. When you get past the perimeter, It's no longer safe.
  - With the range of new use cases that need to be supported,
    - from BYOD to fixed function devices,
    - from accessing legacy web apps to new cloud-based app development and services,

    IT is left with the challenge of working with a varied set of non-integrated tools while striving to achieve regulatory compliance and security at the same time.
- Compliance oriented
  - Compliance meets the requirements of auditors, or specific government mandates, rather than addressing the biggest current threats.
  - The danger is that we may mistake compliance with security standards for actual security.
  - They are two very different things, and some of them only deal with past threats.

Traditional Security: Seriously Broken (3/3)

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- Fixed Security
  - A typical approach to security is to assume that the initial design will remain secure over time.
    - It treats security as a fixed target
    - Assuming that innovative attacks will not arise after deployment.
  - Most security designs and implementations follow such a static deployment model, especially for hardware-based security.
  - Once cracked, hardware security can't be recovered quickly or cheaply.
  - In reality, anything, including clever hardware, can be hacked given enough time and effort.

Therefore, new dynamic security approaches treat security as evolving and assume that security must be continually renewed, whether as part of ongoing policy or reactively.

The Heart of the Matter (1/2)

You can’t fight today’s threats with yesterday’s strategies

- While information security risks have evolved and intensified, security technologies and strategies have not kept pace.
- Today, organizations often rely on yesterday’s security strategies to fight a largely ineffectual battle against highly skilled adversaries who leverage the threats and technologies for tomorrow.
- The sophisticated intruders are bypassing outdated defenses to perpetrate dynamic attacks that are highly targeted and difficult to detect.

The Heart of the Matter (2/2)

- Once a targeted attack is accomplished and the network is breached, there is nothing to stop the damage.
- Organizations are still focused on stopping the landing point and not on what they must do.

What's needed

- A new model of information security that is driven by knowledge of threats, assets, and the motives and targets of potential adversaries.
- A new understanding that an attack is all but inevitable, and safeguarding all date at an equally high level is no longer practical.
- Pioneering technologies, processes and a skill set based on counterintelligence techniques.

New Fundamental Challenges to Information Security

Traditional security is more about security of trusted environments

White-Box Security

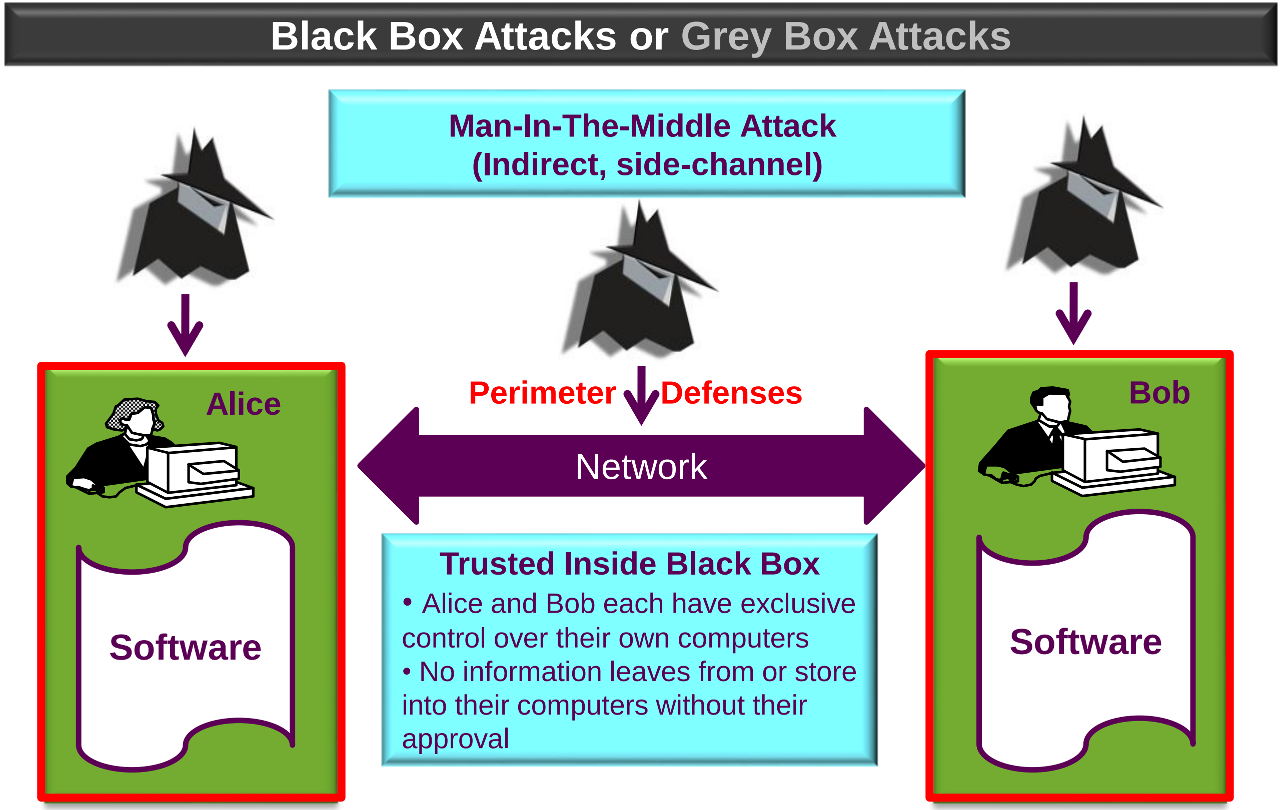
Dynamic and Renewable Security

White-box security and SW protection is more about security of un-trusted environments

WhiteBox Attacks in Real World

White-Box attacks are everywhere within un-trusted environments

Cryptographic Assumption and Traditional Attacks



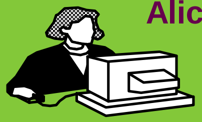
White-Box Attacks

Attackers have open-end powers to do

- ❑ Trace every program instruction
- ❑ View the contents of memory and cache
- ❑ Stop execution at any point and run an off-line process
- ❑ Alter code or memory at will
- ❑ Do all of this for as long as they want, whenever they want, in collusion with as many other attackers as they can find

Man-At-The-End Attack

Alice



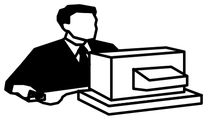
Software

Attacking has much less limitation than protection

Network

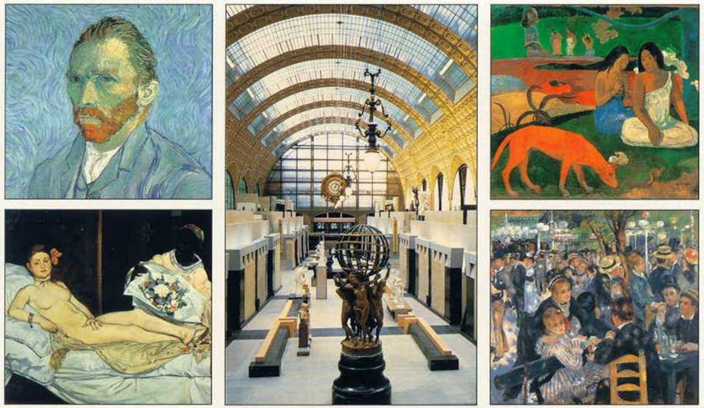
- ❑ Device and environment are un-trusted
- ❑ Attacker has direct access to the machine and software no matter whether it's running or not

Bob is the Attacker

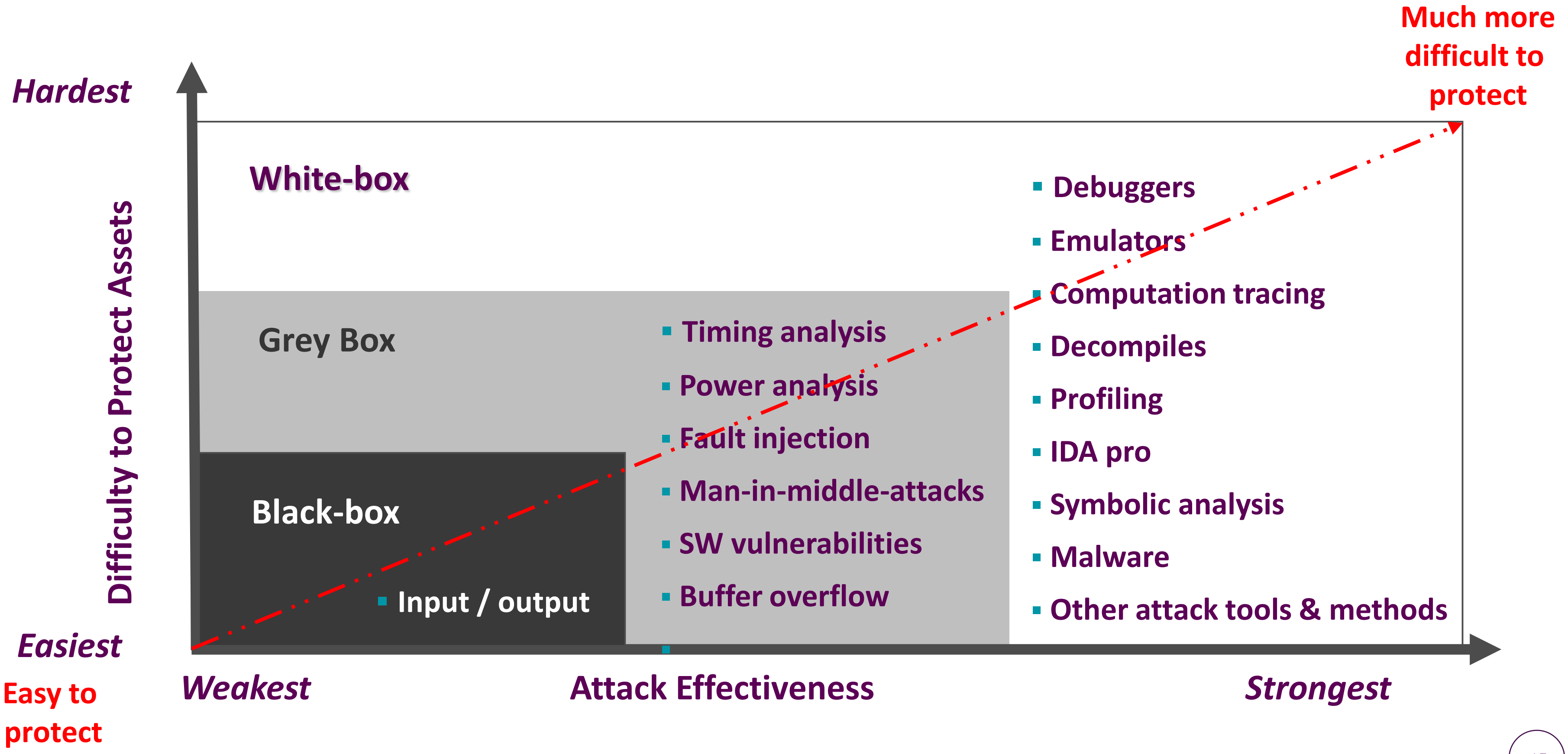


Software

Just Like Security and Protection in Museum

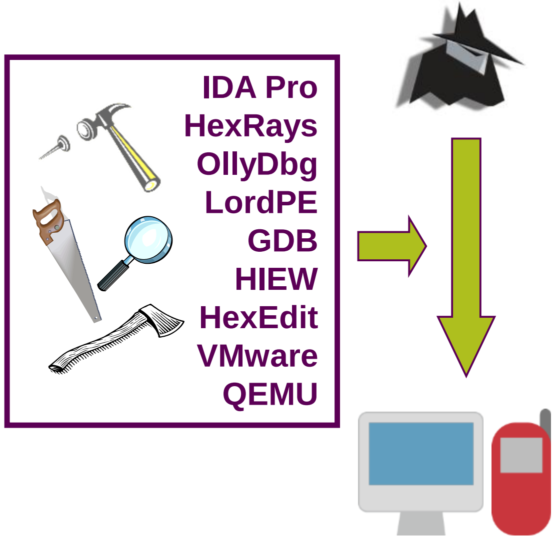


White-Box Security Challenges

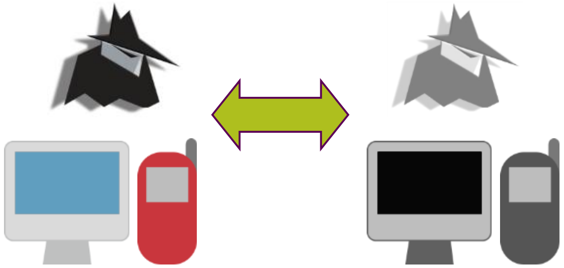


What Are the Threats?

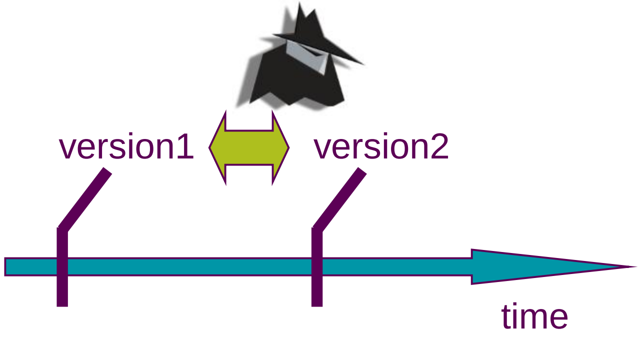
Direct WhiteBox Attack



Colluding Attack



Differential Attack



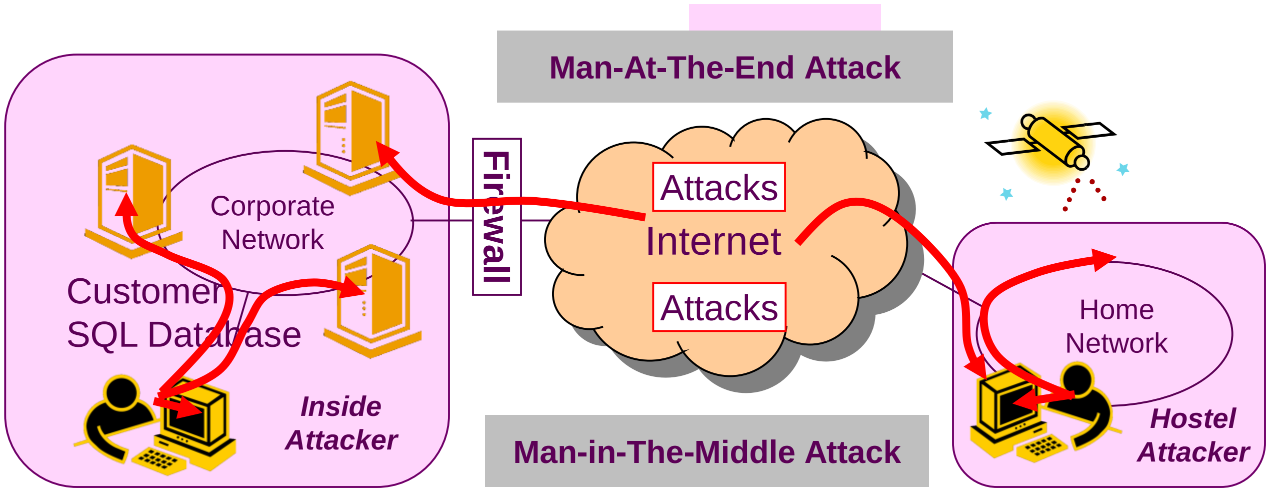
Two Categories of White-Box Environments

Attacks by Human Hackers Directly

Attacks by Malwares and Botnets (Robot-Hackers) Directly

White-Box Environment

Perimeter Defenses Do Not Prevent White-Box Attacks Today



- Firewall
- Authentication (VPN, SSL, …)
- Intrusion detection
- Malware detection and anti-virus
- Cryptography (Black box)
- Physical security
- Secure operation systems
- Software vulnerability check
- Identity management
- Trusted computing

?

Traditional and classic computer and network security technology only provide perimeter defenses

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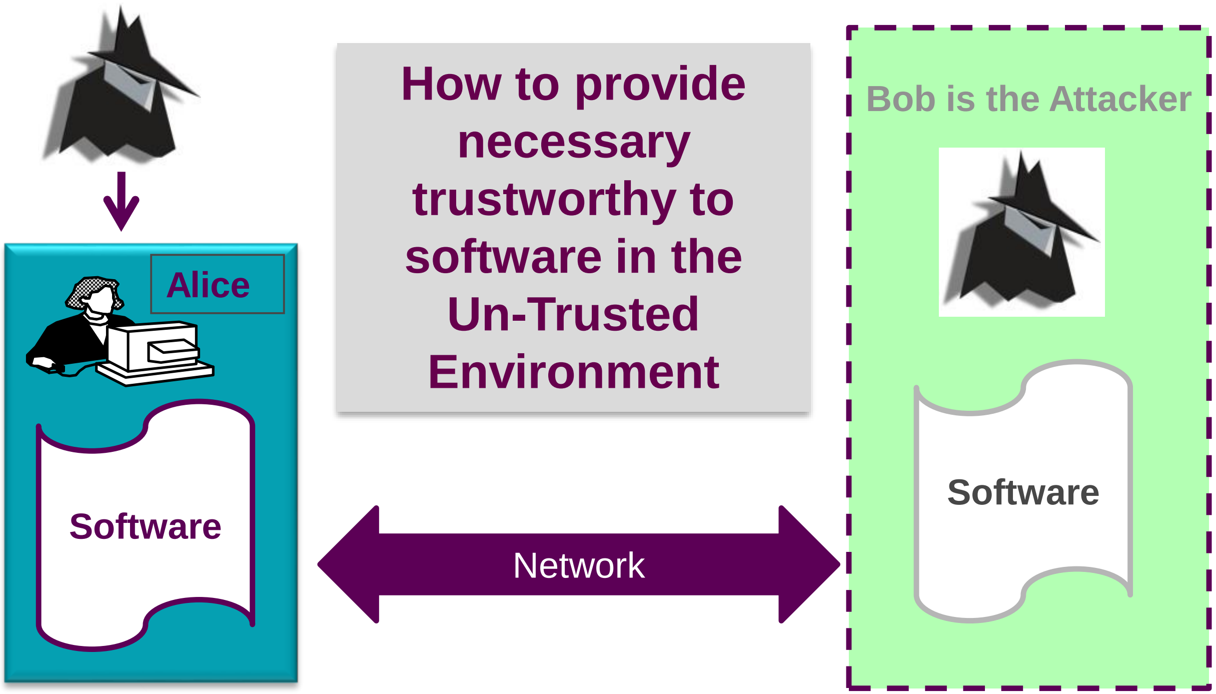
PROBLEM

Perimeter security is invariably bypassed once hackers have physical access

Software Protection Challenges



Software Security: More Than Vulnerability Check and Detection

Both Software Security and Software Protection must become mainstream, not only in the commercial world, but also in the research community

White-Box Vulnerabilities – Example 1

```
#include <stdio.h>
main() { /* Validate the users input to be in the range 1-10 */
    int number; int valid = 0;
        while( valid == 0 ) {
            printf("Enter a number between 1 and 10 -->");
            scanf("%d", &number);

            /* assume number is valid */
            valid = 1;
            if( number < 1 ) {
            printf("Number is below 1. Please re-enter\n");
            valid = 0;
        }
        if( number > 10 ) {
            printf("Number is above 10. Please re-enter\n"); valid = 0; }
    }
    printf("The number is %d\n", number ); }
```

Important constants are exposed in memory

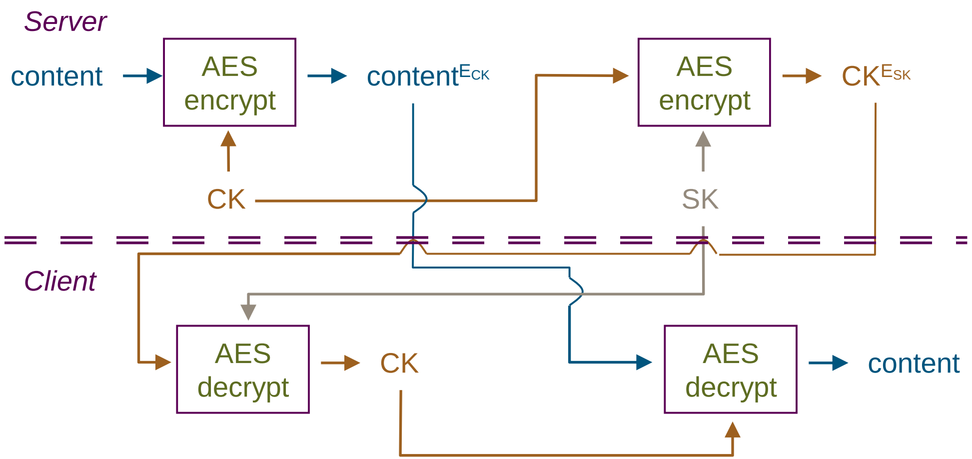
Function calls can be snipped and snooped

Operation can be modified statically and dynamically

Branches can be jammed dynamically

All vulnerabilities must be prevented by SW protection

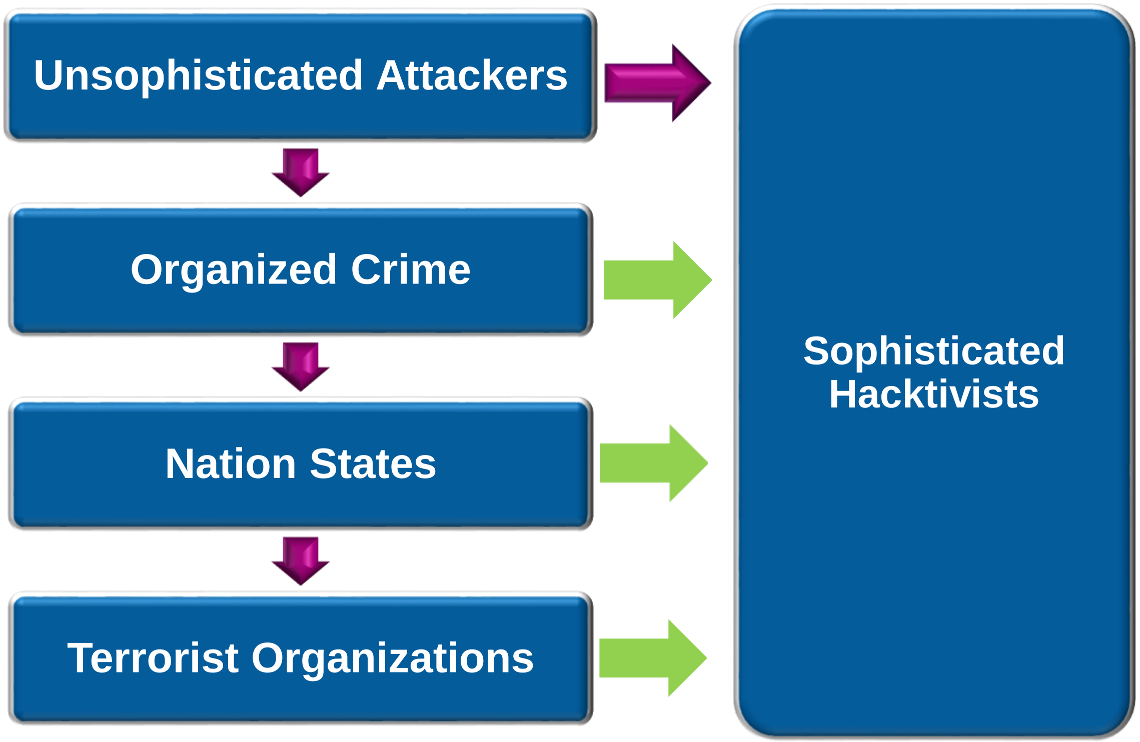
White-Box Vulnerabilities – Example 2



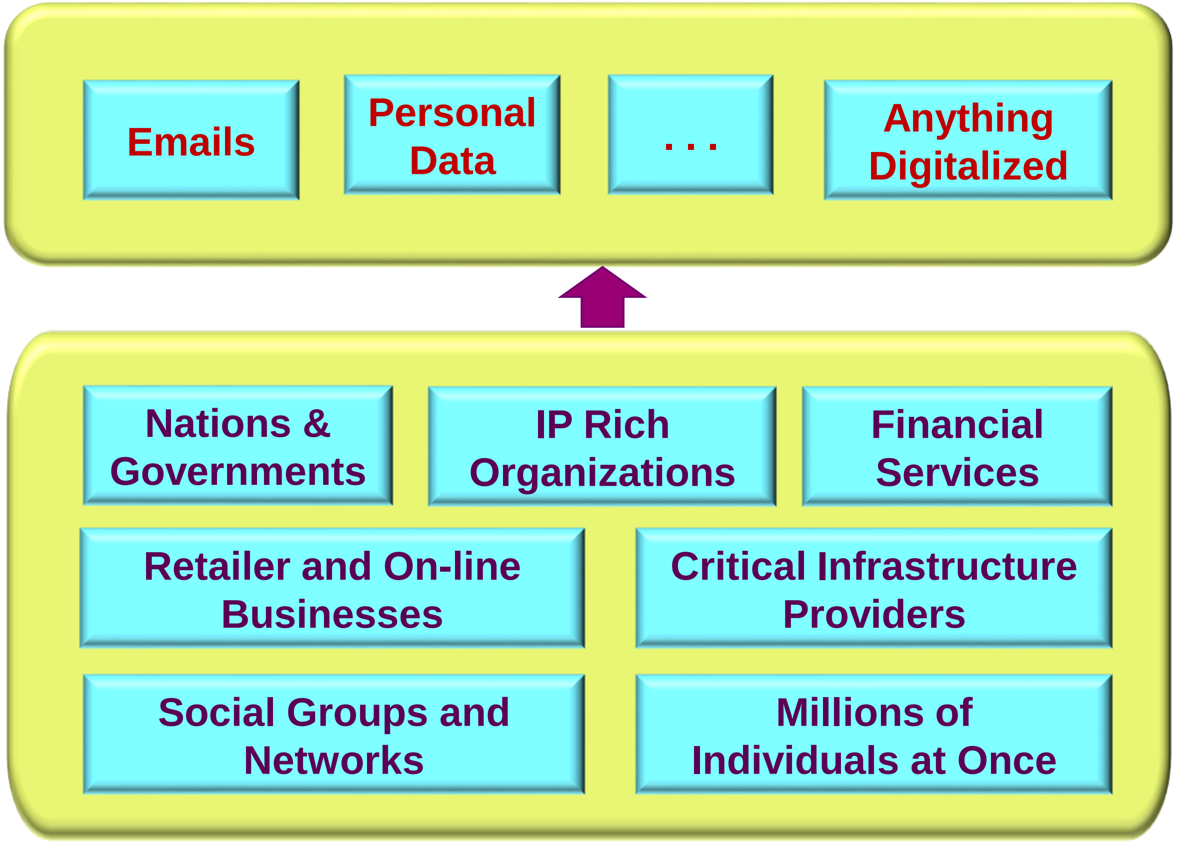
- Session key is sent in the clear
- Content key is exposed on the client
- Content is exposed on the client
- Session and content keys can be extracted during use

All vulnerabilities can be prevented using White-Box Crypto

Who Are the Hackers?



Attack Targets – Digital Assets



Attacks on Software

Software is susceptible to different attacks

Tampering

- Data lifting
- Code lifting
- Modifying control flow
- Data/program file replacement
- Branch jamming

Reverse engineering

- Runtime memory inspection
- Disassembly
- Differential attack
- Collusion
- Reverse control flow
- Interactive debugging
- Process snooping

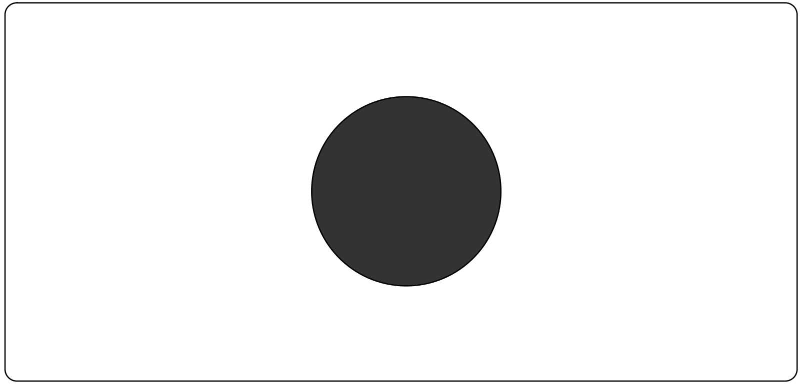
Profit

- Automatic attack
- Redeployed data files
- Dynamic library exploits
- Unauthorized use

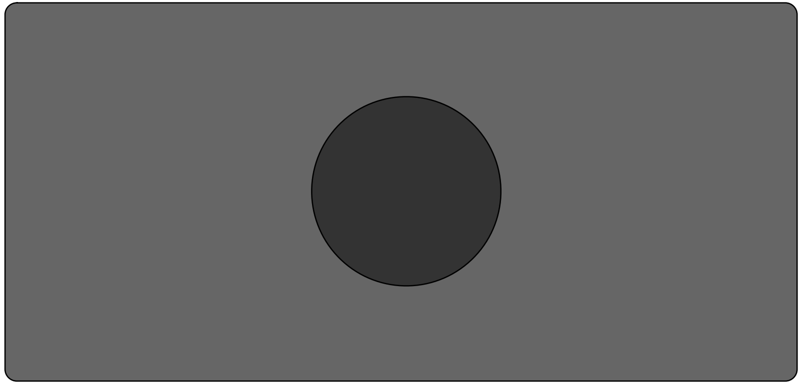
Different attacks need different protection

Specific Problem: Black Hole Effect

- The black hole effect occurs when part of the application is very secure but the rest is in the clear
- Hackers mostly attack the boundary between the secure and the non secure parts of a program



- To Fix the Black Hole effect
  - More lighter obfuscation in the rest of the program
  - Faster generated code so that more security can be use in the white area
  - Transcoder Levels for low security on the rest of the application
- Blur the boundary between the secure and the rest of the program at low cost



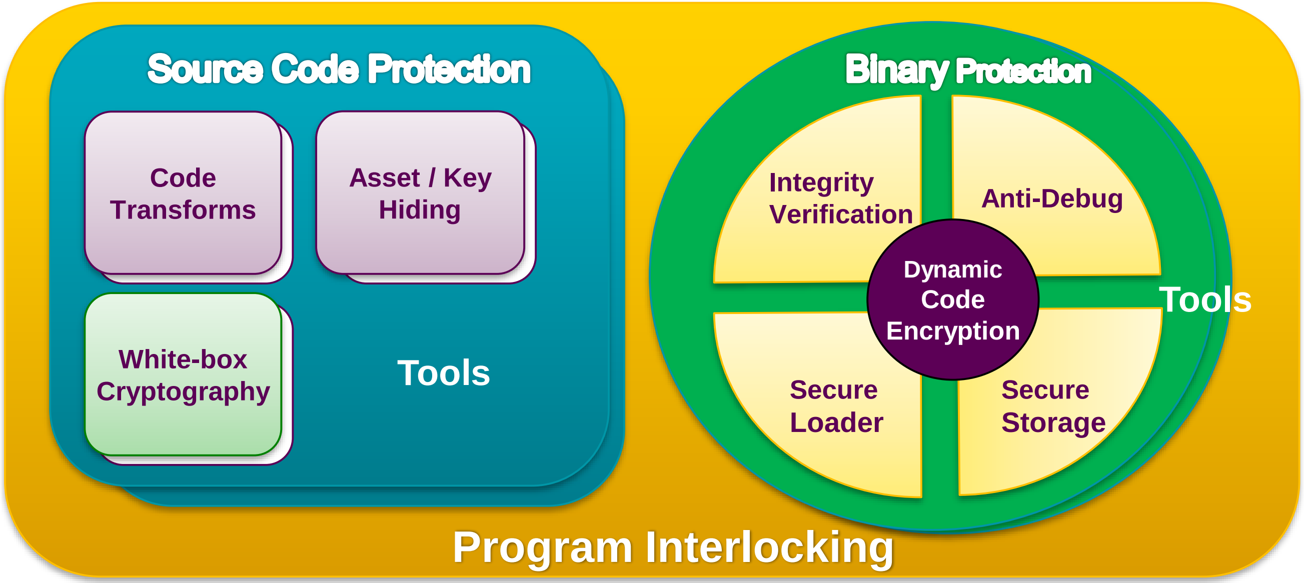
Power of Software Protection

White-Box security is new security paradigm well beyond traditional computer and network security

Key Objectives of Software Protection

- Resist static and dynamic reverse-engineering
- Resist tampering (i.e. unauthorized modifications)
- Resist cloning (i.e. moving software to a node it is not authorized to run on)
- Resist spoofing (i.e. having software use false identification information, such as over a network)
- Hide both static and dynamic secrets, as they are created, moved, and used.
- Impede the production and distribution of useful “crack” programs.
- Facilitate timely, intelligent responses to crack incidents.

Software Protection at All Levels



- Use software protection tools and libraries to make software self-protected at build-time
- Provide a comprehensive approach to software security

Multi-Layered and Interlocked Protection

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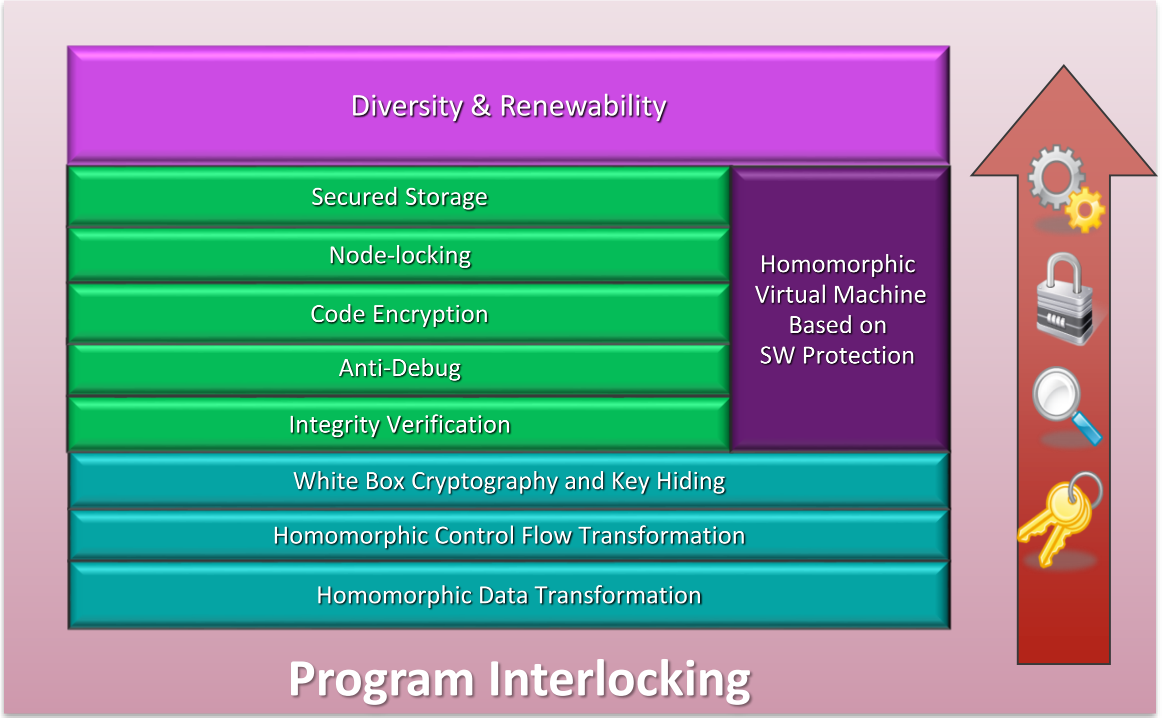
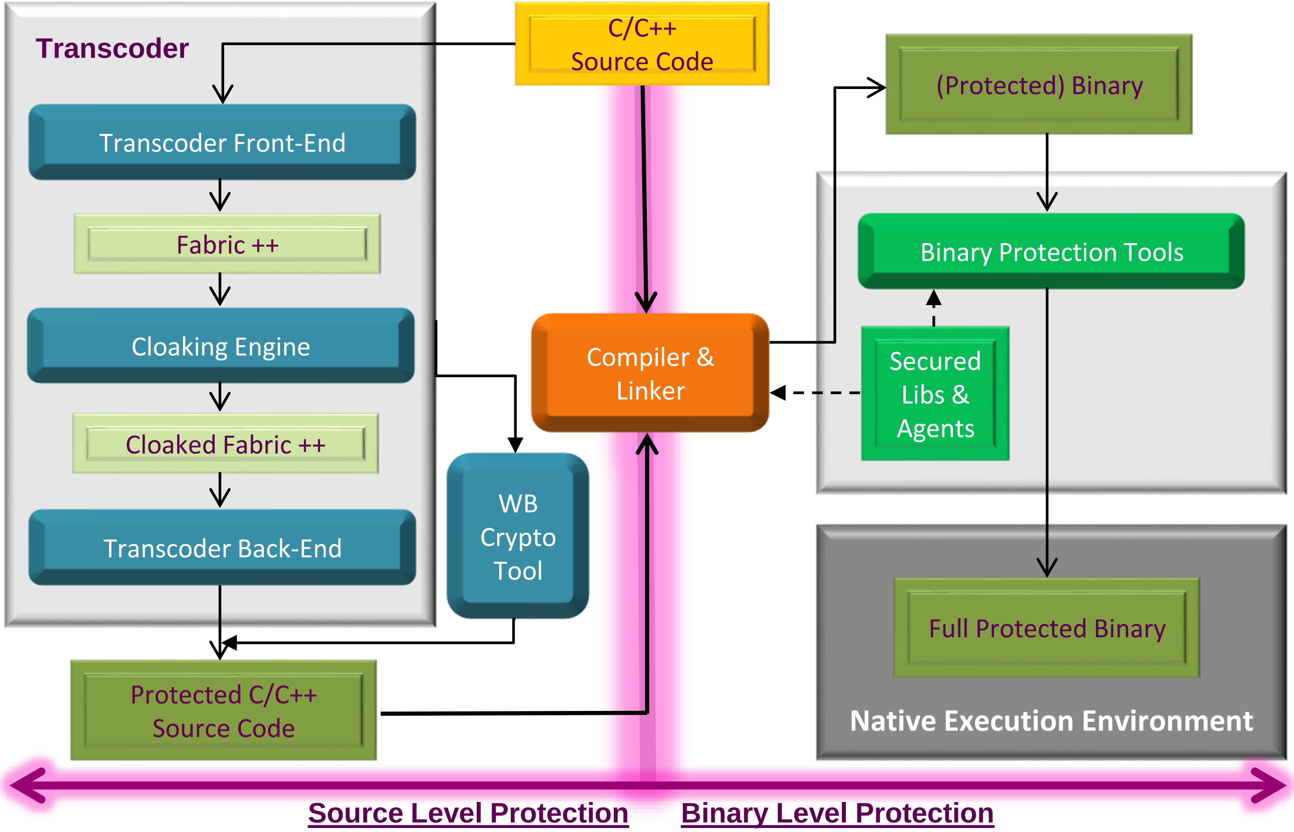
- Protect application code against a collection of attacks
- Provides a multi-layered and interlocked defenses
- Flexible and modular to choose the right combination of defenses

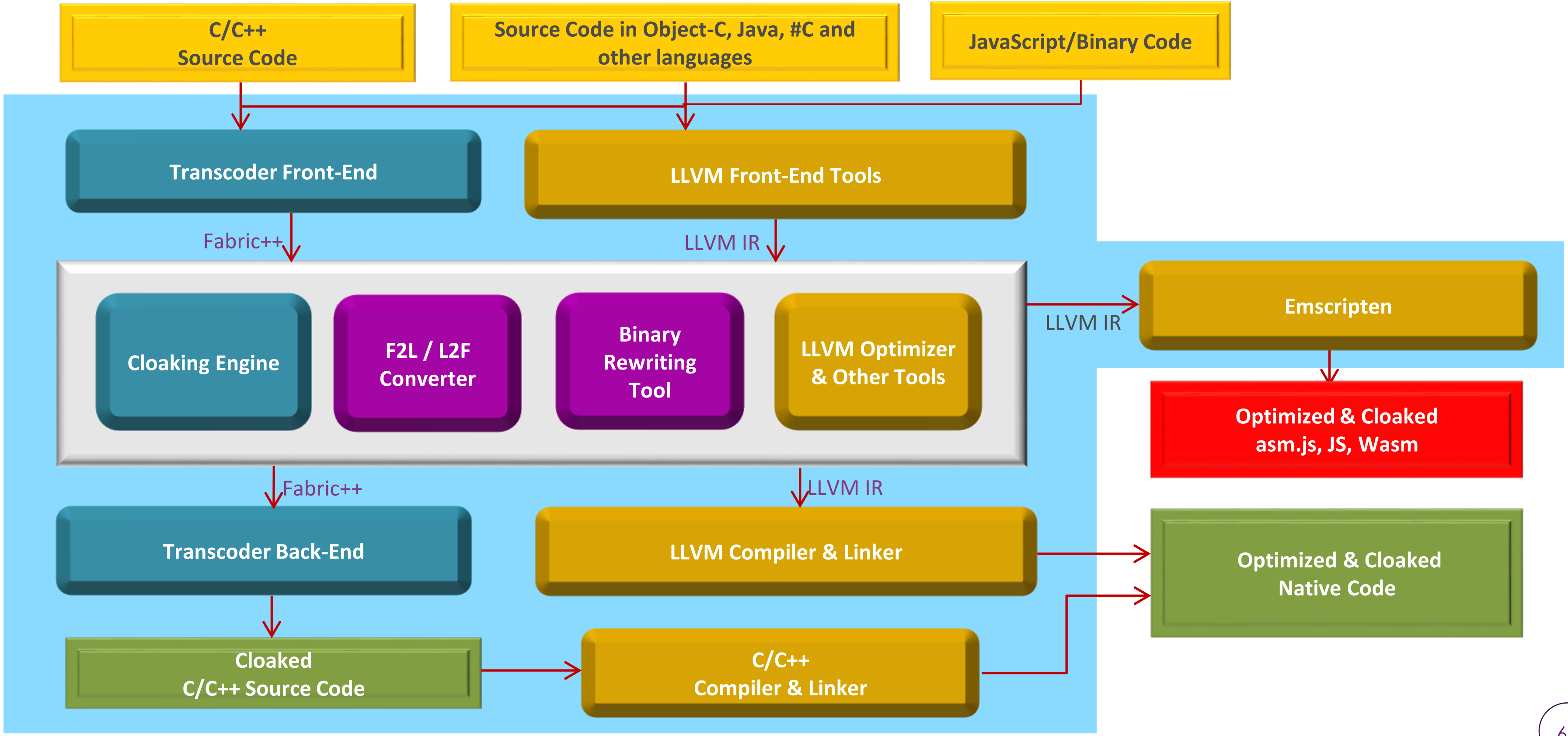


Making security inseparable from your software

C/C++ Protection and Binary Protection

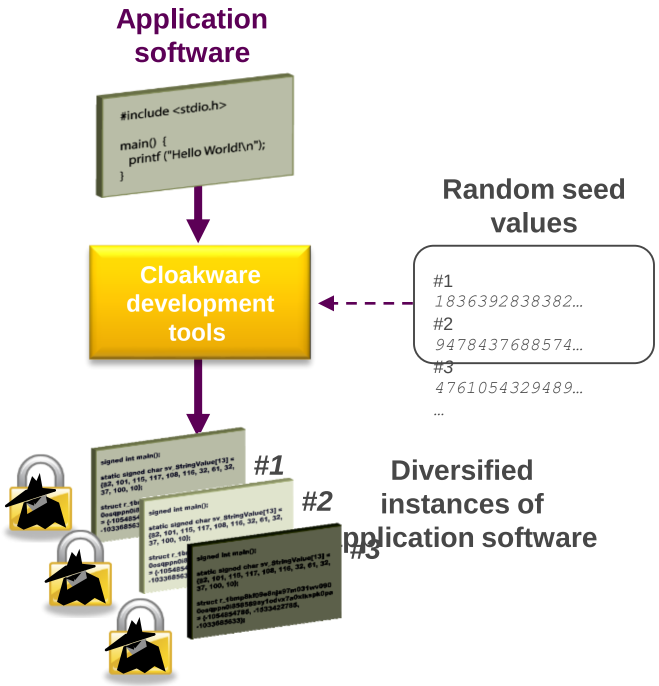


Unified Cloaking Toolset



Software Diversity: the-State-of-the-Art

- Diverse software instances are functionally equivalent but structurally and semantically diverse
- Each instance must be attacked separately by a skilled hacker
- Dramatically increases the work to create an automated attack tool
- The production of diverse instances is fully automated by the Cloakware tool chain



Value of Software Protection

Secured Input
Authentication, validation, integrity, confidentiality of input data

Hide Algorithms & Computations

Tamper Detection

Secured Output
Authentication, validation, integrity, confidentiality of output data

Tamper Resistance
Makes it hard to modify the code's data and control flow

Hide Internal Data
Including internally initialized data

Damage Mitigation

Power of Protection Technology (examples)

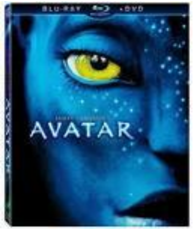
Technology	Prevent Analysis		Prevent *Effective* Tampering*		Foil Automated Attacks	Supports Software Diversity
	Static	Dynamic	Static	Dynamic		
Data Flow Transforms	✓	✓	✓	✓	✓	✓
Control Flow Transforms	✓		✓	✓	✓	✓
White-box Crypto	✓	✓			✓	✓
Program Interlock	✓	✓	✓	✓	✓	✓
Integrity Verification			✓	✓	✓	✓
Anti-Debug		✓		✓	✓	✓
Code Encryption	✓	✓	✓		✓	✓

* Tampering which causes software to fail is less threat than software modified to achieve a hacker's specific desired result

Deployments are Rarely Simple

- Multiple Languages
  - C, C++, Java, C#, .NET, JavaScript, Flash, Ruby, Perl, Ajax
- Heterogeneous System Run Environments
  - Android: Linux, Native & Dalvik VM
  - BluRay Disc: BD+ VM & Native & BD-J
  - WinMobile: C#, Native

- Multiple Platforms
  - Adobe Flash Access: PC, Mac, QNX, Android
  - Apple iTunes: Mac, Win, iOS
  - Comcast Xfinity: iOS, Android
  - CA: ST40, MIPs, x86, Amino, Broadcom



Security must balance with constraints, in particular, performance

Cloakware for Applications - Built on Core Technology

irdeto

Cloakware for Applications

iOS | Android | Linux | Automotive Grade Linux | GENIVI® | QNX™

Application Protections

API Protection	Jailbreak & Root Detection	Anti-Hooking	Anti-Tamper
Node Locking	Diversity & Renewability	Java Access Control	Anti-Reverse Engineering

Code Obfuscation

- Data Obfuscation
- Function Obfuscation
- Control Flow Obfuscation
- Secure Inlining & Merging
- Control Flow Integrity
- Code Entanglement

Binary Protection

- Application Signing
- Platform Flexible Integrity Verification
- Anti-Debug
- Secure Loader
- Platform Flexible Fingerprinting

Cryptography

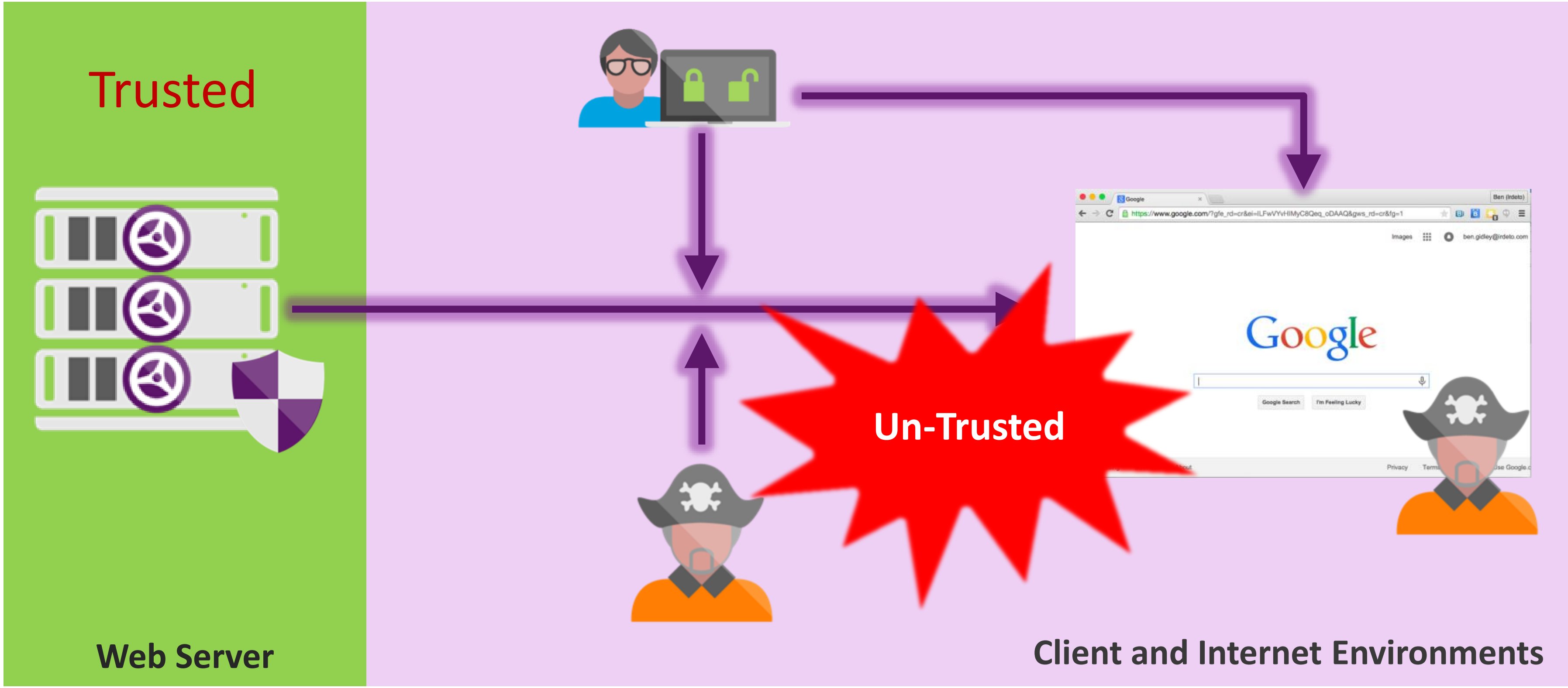
- White box Cryptography
  - RSA
  - AES
  - ECC
  - 3DES
- Whitebox PRNG
- Secure Store

Security Tools

- Secured Libraries (FlexLib)
- Smart Assembly
- Key Transformations
- Secure Code Injection
- Security Plugins
- Secure Heap

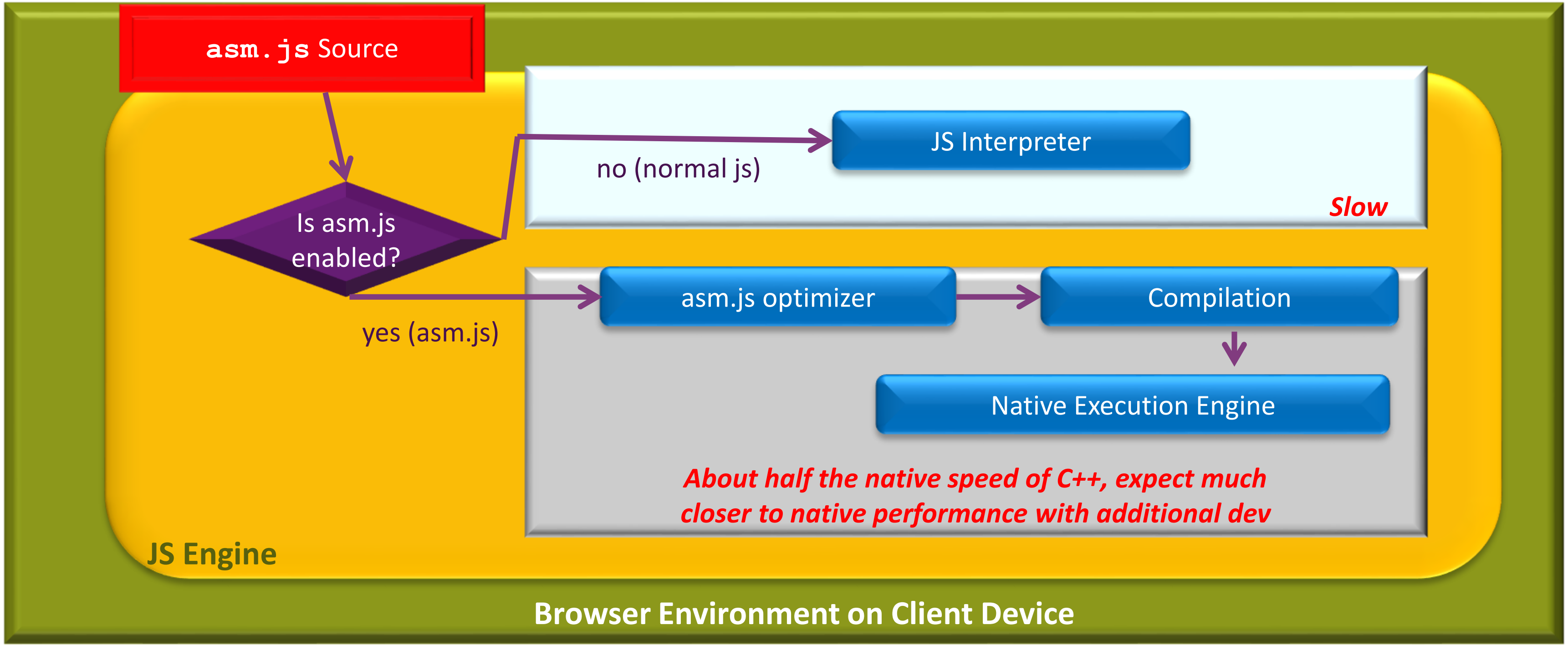
Web Application Security Challenges

What can JavaScript and Webassembly Protection do?



Trusted
Un-Trusted
Google
Web Server
Client and Internet Environments

Browser with asm.js Support and Wasm



As the *next evolutionary step of asm.js,* **WebAssembly (Wasm)** is a new project being worked by Mozilla, Microsoft, Google and Apple to create a new standard, that defines a portable, size- and load-time-efficient format and execution model specifically designed to serve as a compilation target for the web and non-web.

Is it possible to protect web applications running in a browser environment?

It is Impossible!

Don't know how you can?

Rest of the world does not believe that this can be done by using software protection technologies

Irdeto is a leader to develop new technology to protect and secure web applications by protecting JavaScript and Webassembly

- Created a trusted digital platform for a protected web application inside web browsers
- Enforce integrity of the web application and protect 'business logic' running in web browsers
- Allow businesses to engage with their users in a more secure and reliable fashion to protect their business models

Now, a web application can be protected by itself even if in a hostile web browser

Overview of JavaScript/WASM Protection Technology

- **JS/WASM Cloaking Technology**

  New JS protection tool chain combines the Irdeto Transcoder with other enabling technologies such as LLVM and Asm.js

- **Direct JS Protection**

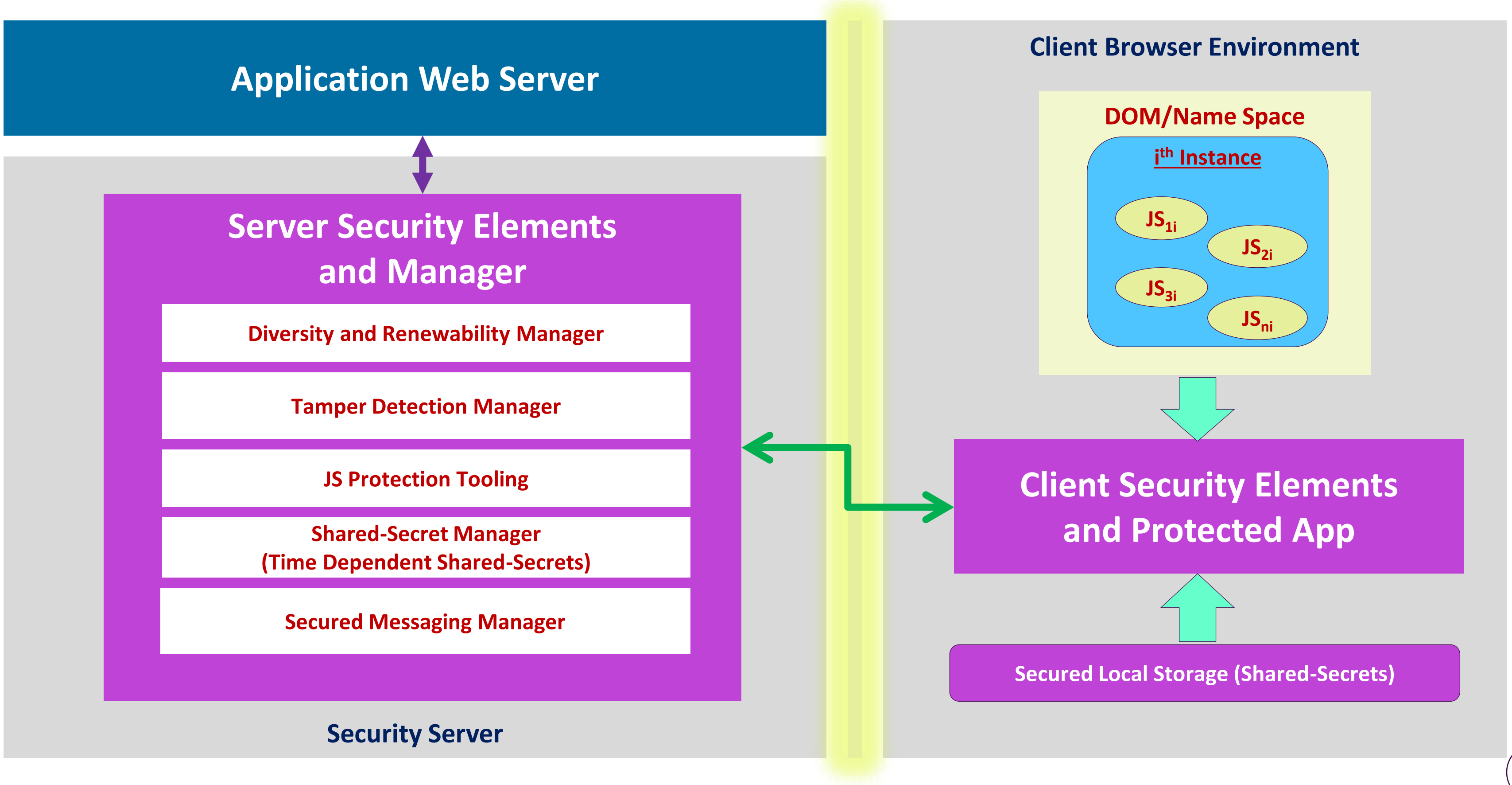
  New set of security protections applied directly to JS code analogous to Irdeto's source and binary code protection features

- **New Trusted Platform for Tethered Web Applications**

  A new trust model leveraged JS/WASM cloaking and direct protection capabilities above

  - Server-based root-trust and security enforcements
  - Code and security behaviors: dynamic, randomized, agile, diversified and renewable during security life cycle
  - White-box encrypted messaging between client & server

New Trusted Digital Platform of Tethered Web Applications

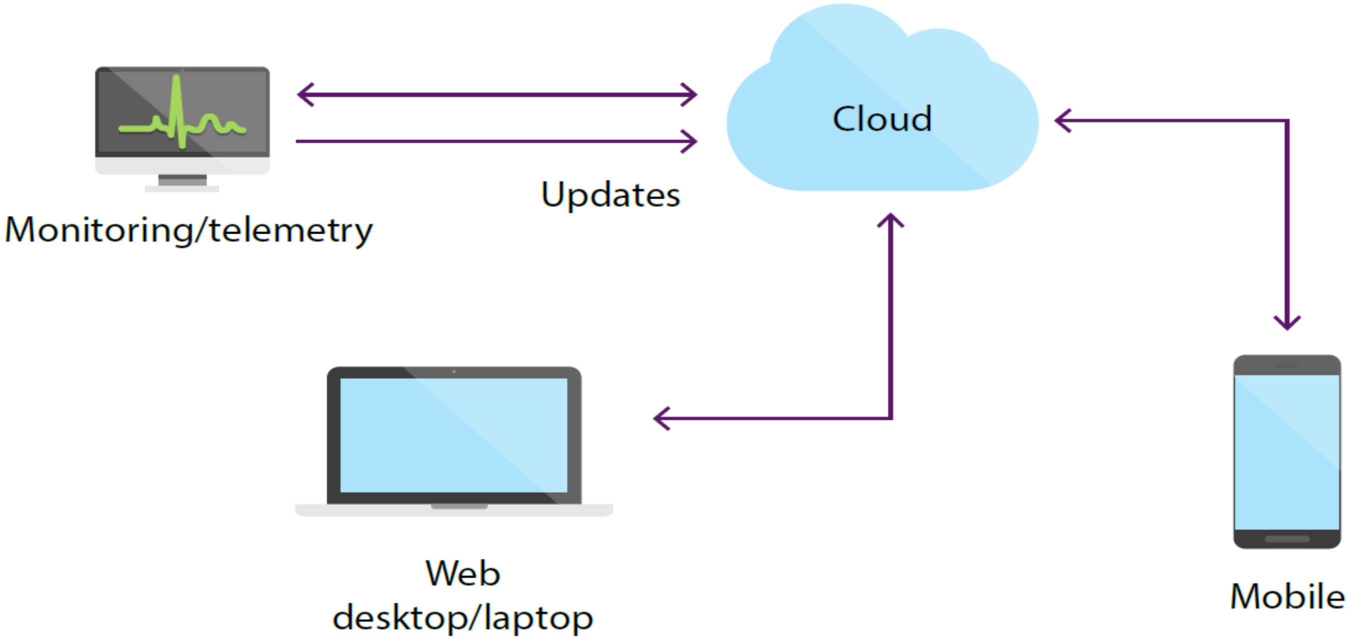


New Business Perspectives of Web Protection

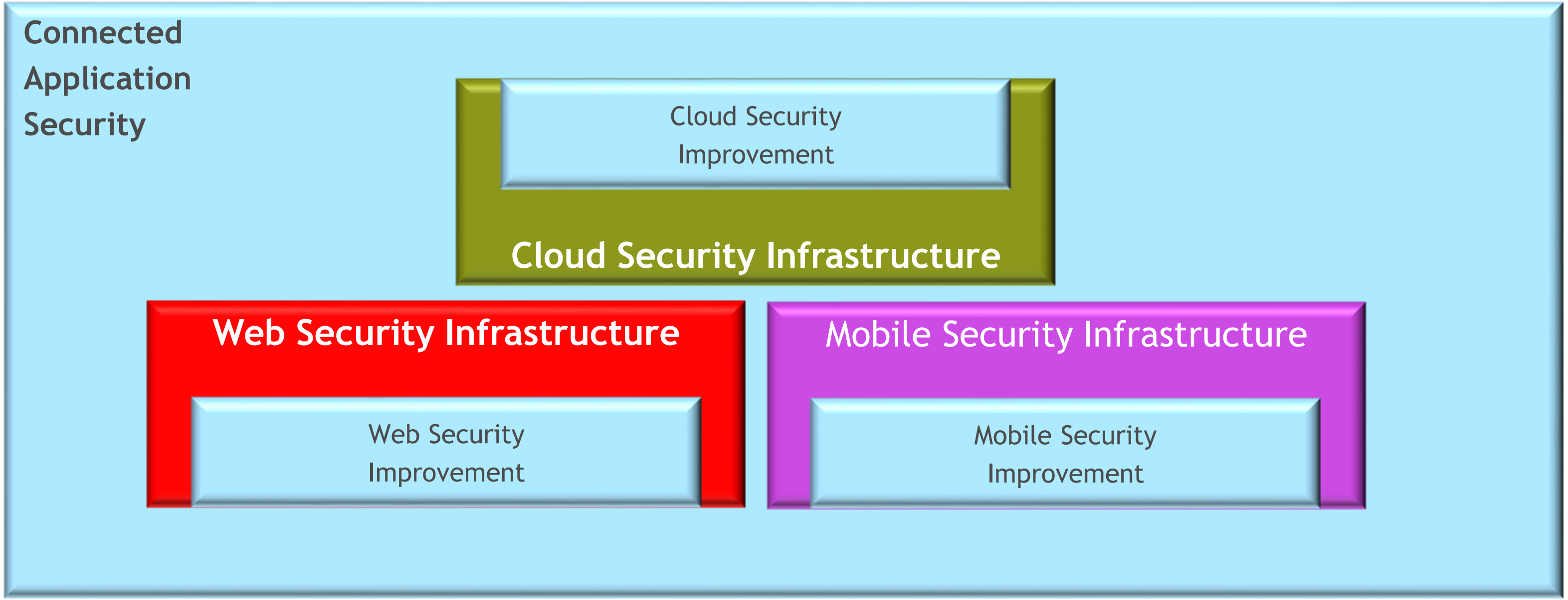
Connected Application central based Security Model

Trusted model to address both man-in-the-middle and man-at-the-end attacks

Connected Application Topology



Application Centric Trusted Model

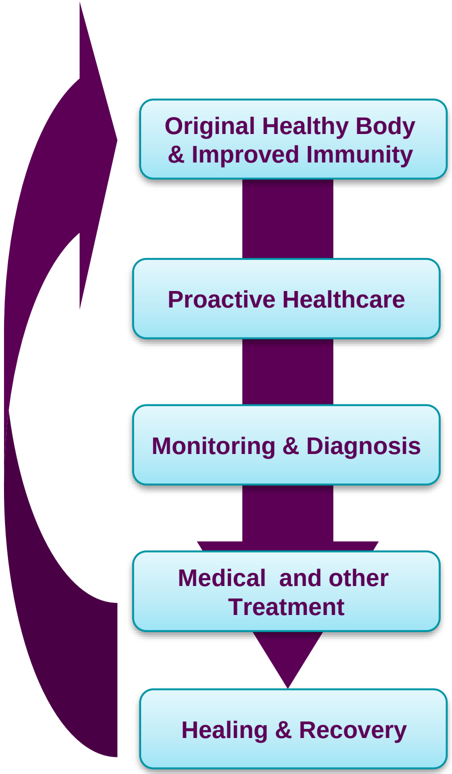


E. G. AbdAllah, M. Zulkernine, Y. X. Gu, and C. Liem, “TRUST-CAP: A Trust Model for Cloud-based Applications”, IEEE 41st Annual Computer Software and Applications Conference on the 7th IEEE International COMPSAC Workshop on Network Technologies for Security, Administration and Protection (NETSAP), Torino, Italy, July 2017, pp. 584-589, DOI: 10.1109/COMPSAC.2017.256.

Software Security Lifecycle and Digital Asset Protection

Like the lifecycle for human health protection, the security lifecycle of a digital asset application mandates protection from creation, through distribution and then ultimately consumption from being deployed in the field

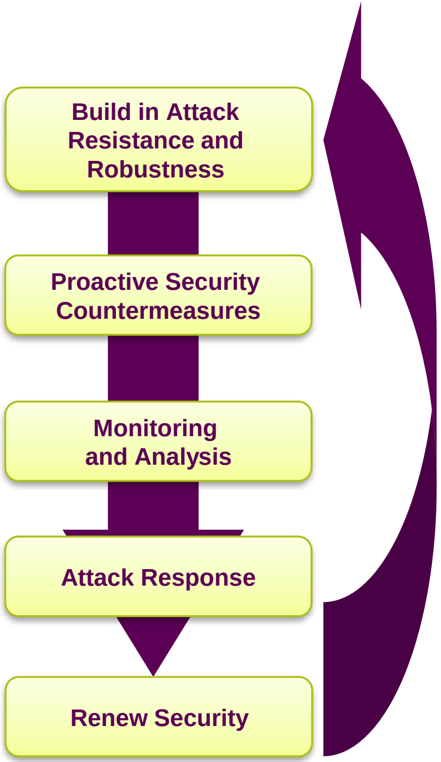
Security Lifecycle Management



Human Body Protection

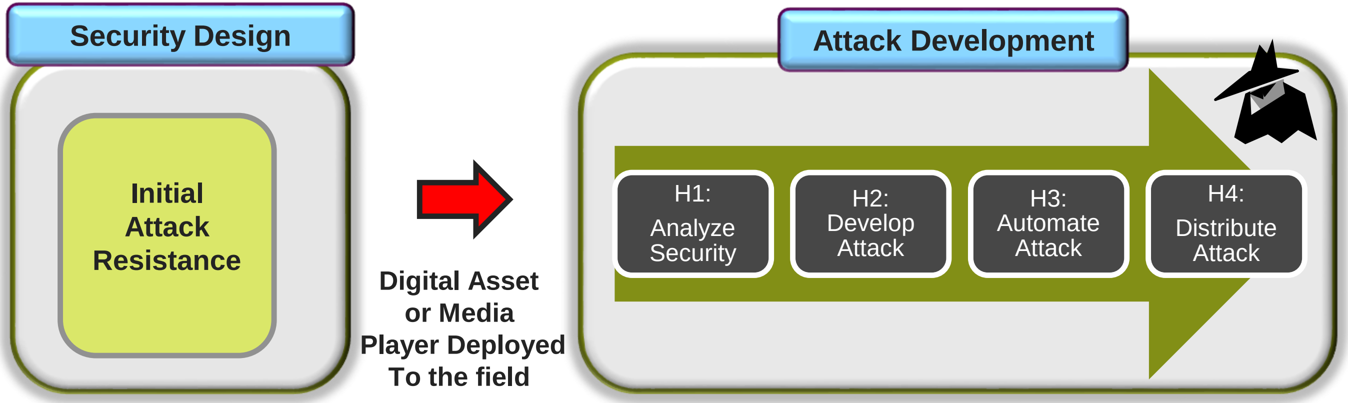
Healthcare is one of the largest industries and fields of research

- Software security is a young field
- Software protection is becoming main stream of system security
- Irdeto has best-in-class tools and technology for software security lifecycle



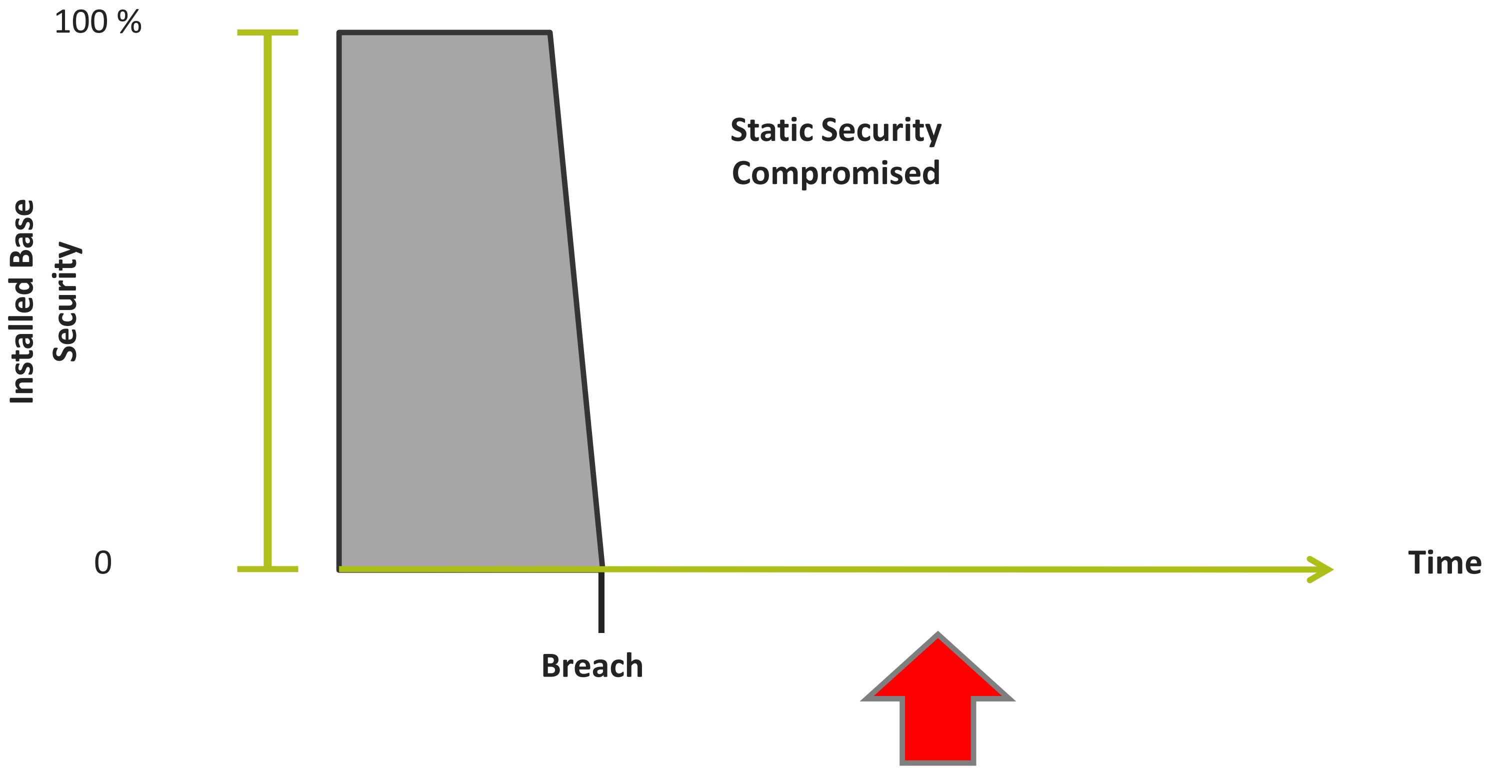
Software Protection

Traditional Security Model



- Typical approach to security is to assume that the initial design will remain secure over time
- Anything can be hacked given enough time and effort
  - Set top boxes, PC apps, Mobile devices, CE devices
- Content owners want to know, “What is your security strategy”?
  - How will you limit potential damages if there is a breach?
  - What is your renewability strategy?

The Result of Static Security



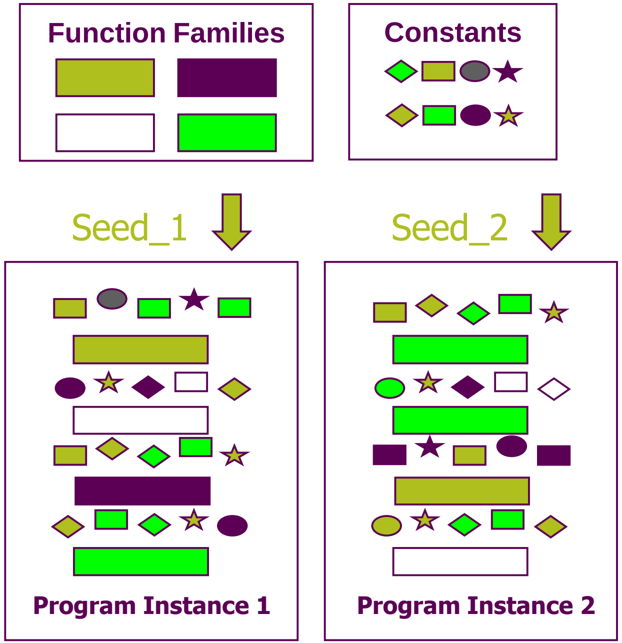
What is Dynamic Security?

Dynamic Security is a security model that enables the protection of digital assets against unauthorized use through the upgrade and renewal of the underlying security in the field.

- Proactive prevention
  - Monitor hacker channels to understand attack techniques and methodologies
  - Apply security updates to reset the hacker's clock
- Reactive reduction
  - Limits the impact of a breach before it has a significant impact
- Benefits:
  - Disrupt potential hacks before they happen
  - Mitigate impact of a security breach
  - Minimal disruption of business

Software Diversity

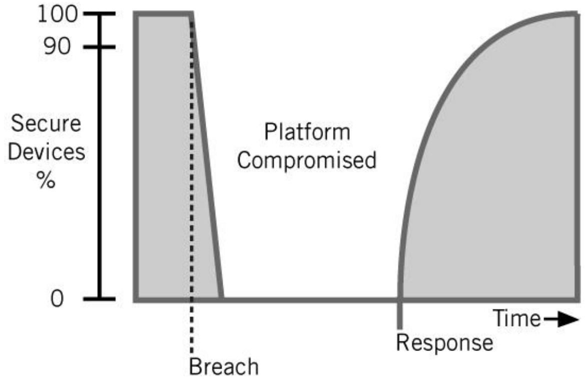
- All program Constructs can Be Diversified
- Randomly Chosen:
  - Order & program Layout
  - Function Families
  - Constants
- Seeded Build
  - Reproducibility
- Diversity Control and Opportunities
  - On the source level
  - At the compilation time
  - On the library level
  - At the link time
  - On the binary level
  - Combination above
- Static and Dynamic Diversity



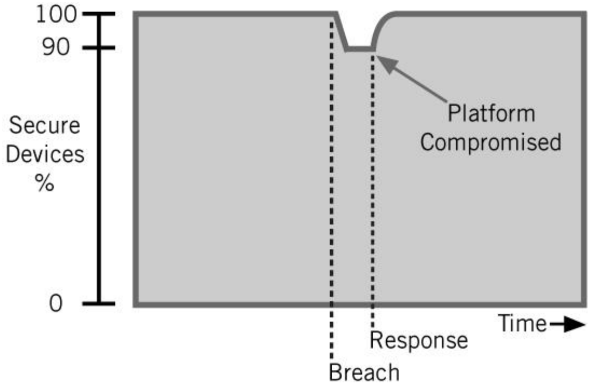
Any software protection techniques can make own contributions to software diversity

Static Security vs Dynamic Security

Static Security



Dynamic Security



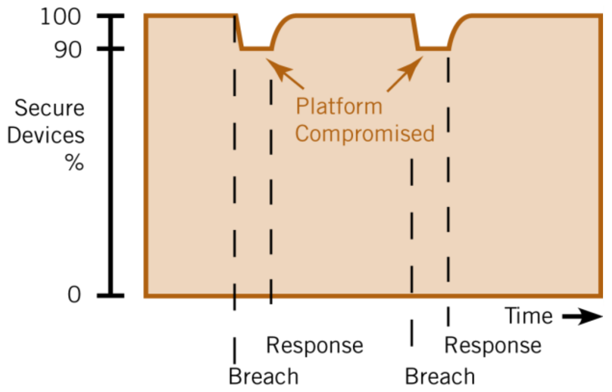
Once static security breaks, the entire security is gone and hard to be restored

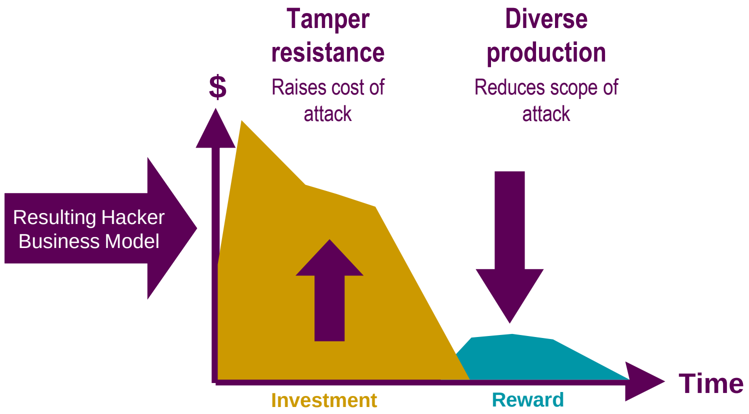
Once dynamic security breaks, the security can be renewed and restored immediately in a planned way

Attack Mitigation and Recovery

Diversity! Renewability!! Countermeasure!!!

- Strong attack response
- Reduces duration of attack





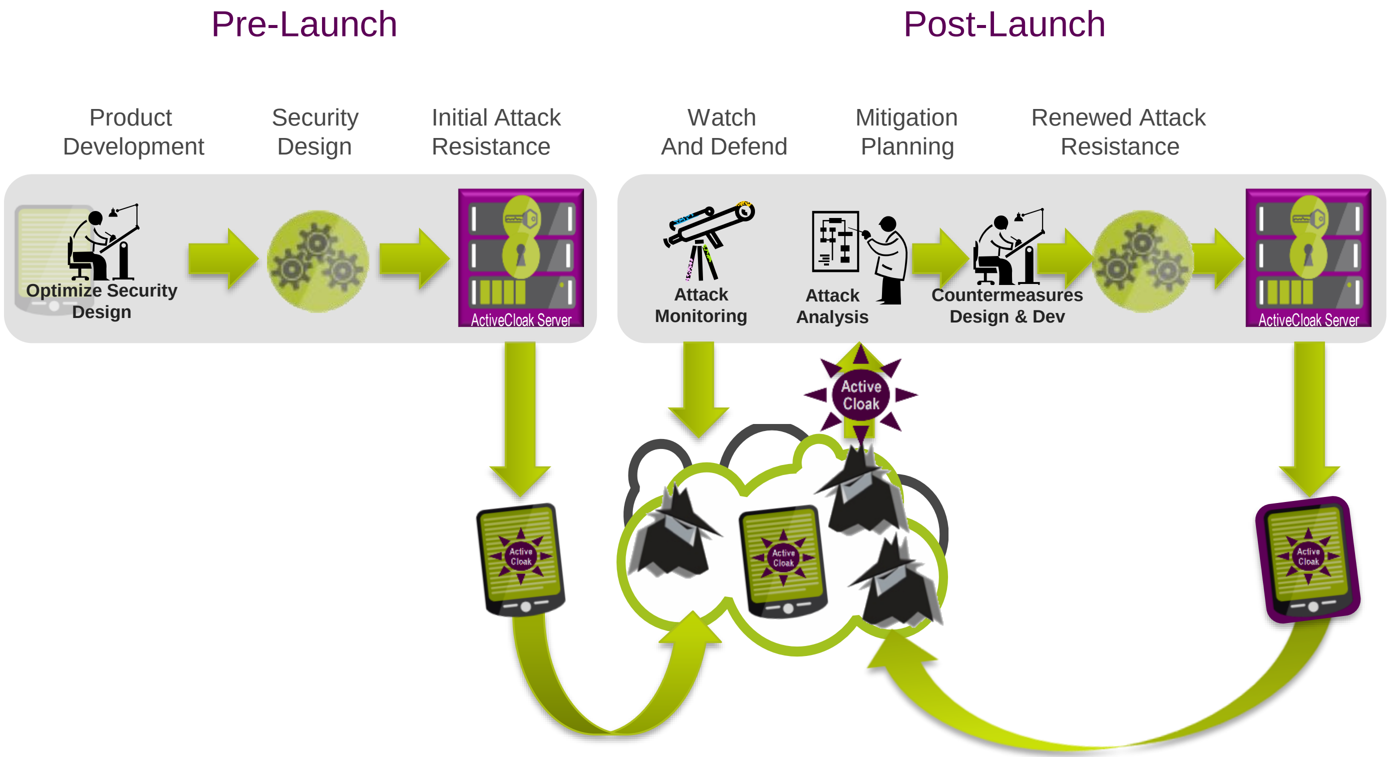
Software Diversity Benefits

Minimize scope of attack -- Prevent automated attacks

Provide rapid recovery in the event of an attack

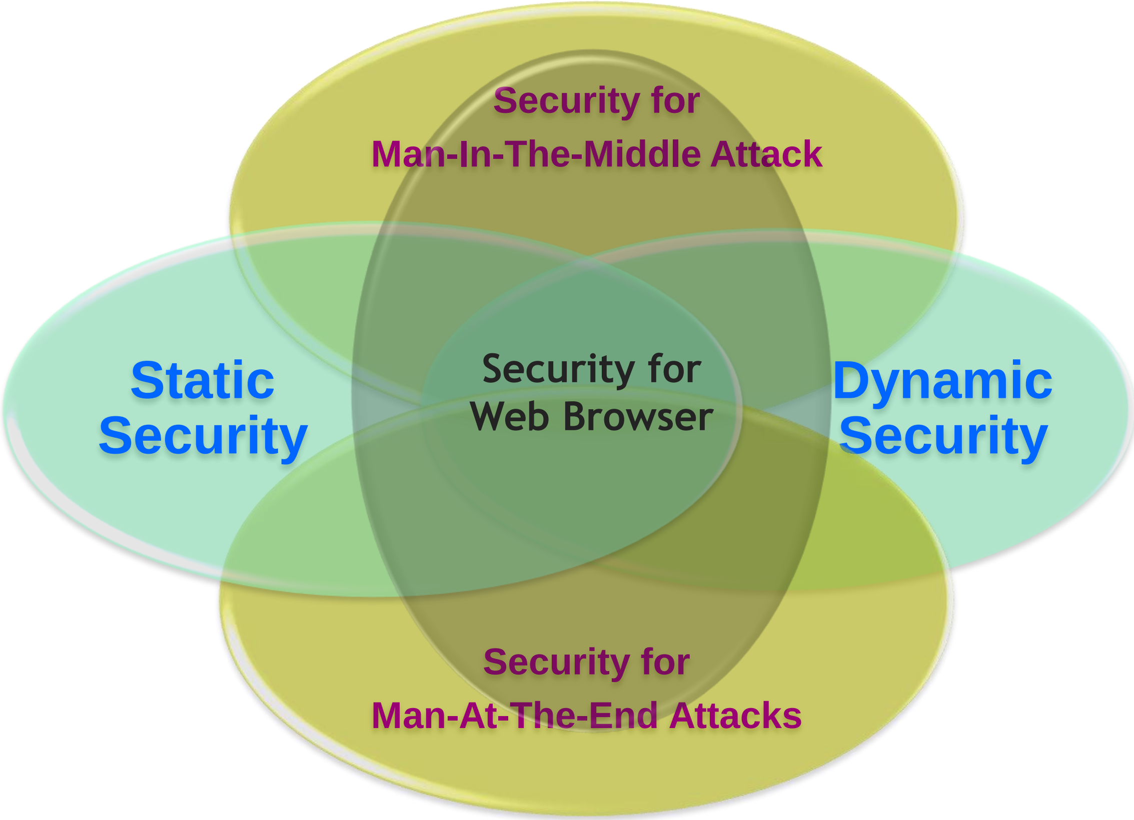
Make the business unattractive to the hacker

Dynamic Security and Lifecycle Management



New View of Information Security and New Research Opportunity

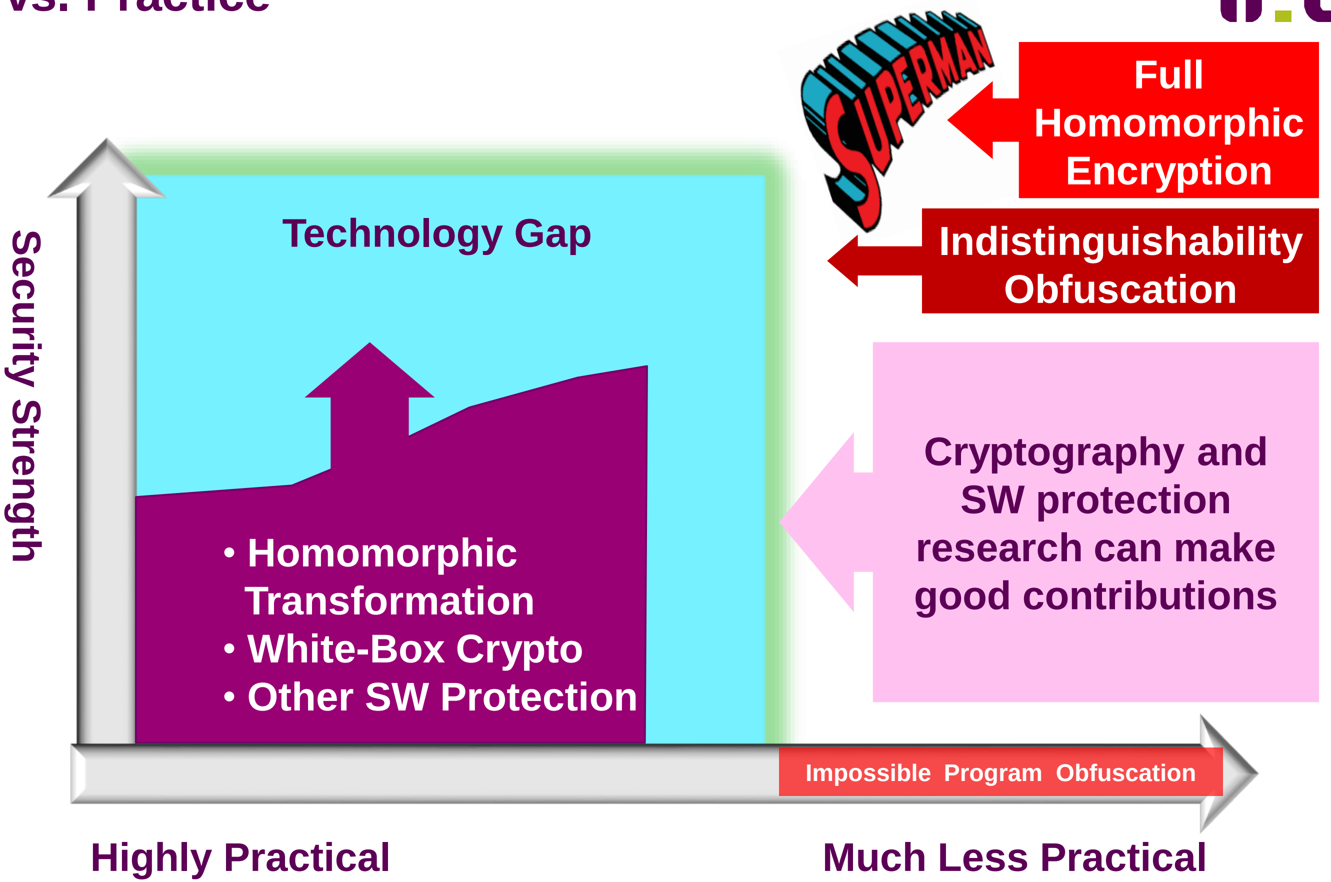
New View of Information Security



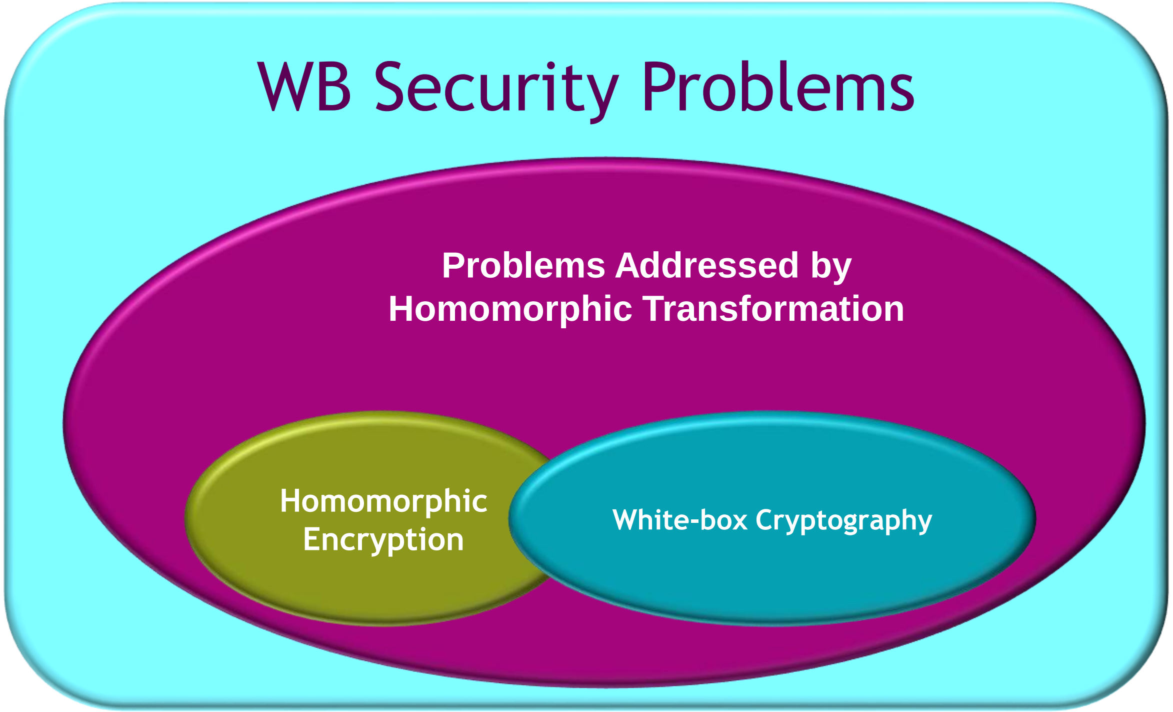
BlackBox Crypto *vs.* WhiteBox Crypto *vs.* Ideal SW Protection

Software Protection is largely different transformations with very different security profile comparing to traditional security

Security vs. Practice



WB Security Problem Space



Big Unknown: Protection Measurement (1/2)

It is very difficult by adapting any existing theories and methods to develop commonly acceptable metrics on the effeteness of SW protection.

- Existing software complexity techniques and methods has very little value for resolving this problem
- Current computation complexity theory cannot apply easily and directly to develop a formal model for such a measurement
- Cryptographic analysis methods on black-box security are not applicable well for many cases

Big Unknown: Protection Measurement (2/2)

Some Interesting Observations

- SW protection needs to prevent all attacks but attacking only needs to find one place to break.
- There is no single protection can stop all attacks. Instead, we have to layer and combine different protection techniques into a protected and interlocked security maze.
- More [less] complicated protected software doesn’t mean more [less] secure
- Static measurement is not enough to address security dynamics
- Attacking mainly is a manual process. How to measure the effectiveness of attacks by different skilled attackers?
- Security has to deal with unknown attacks in the future? How?
- Perfect security does not exist! SW security must be relative and renewable!

A good opportunity for research

Work with SW protection professionals to develop measurement model and metrics on SW security and protection (Good PhD research subjects)

Part 3: **White-box Security Patterns**

cloakware®

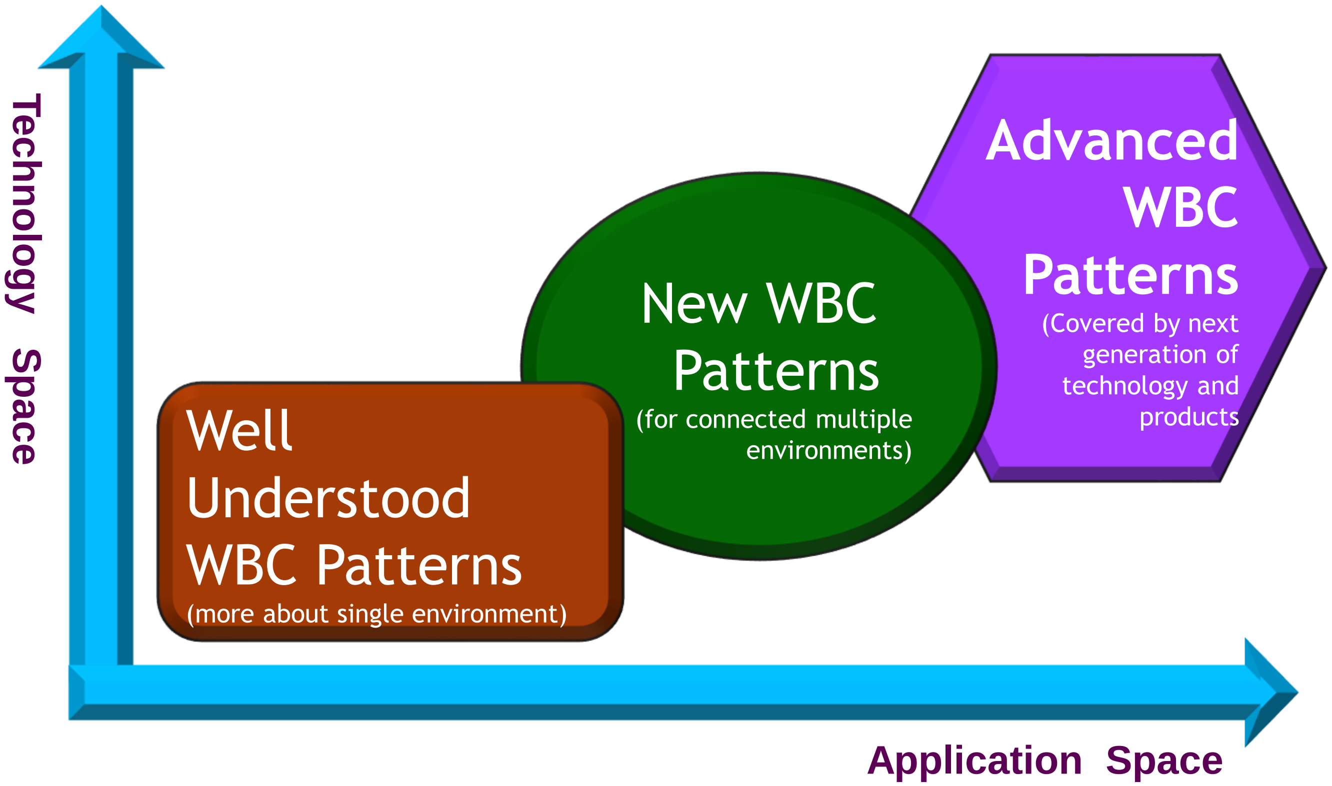
Introduction to White-Box Security Patterns

Software security now is an art not a science. Pattern abstraction is one of valuable steps forward to scientific foundation

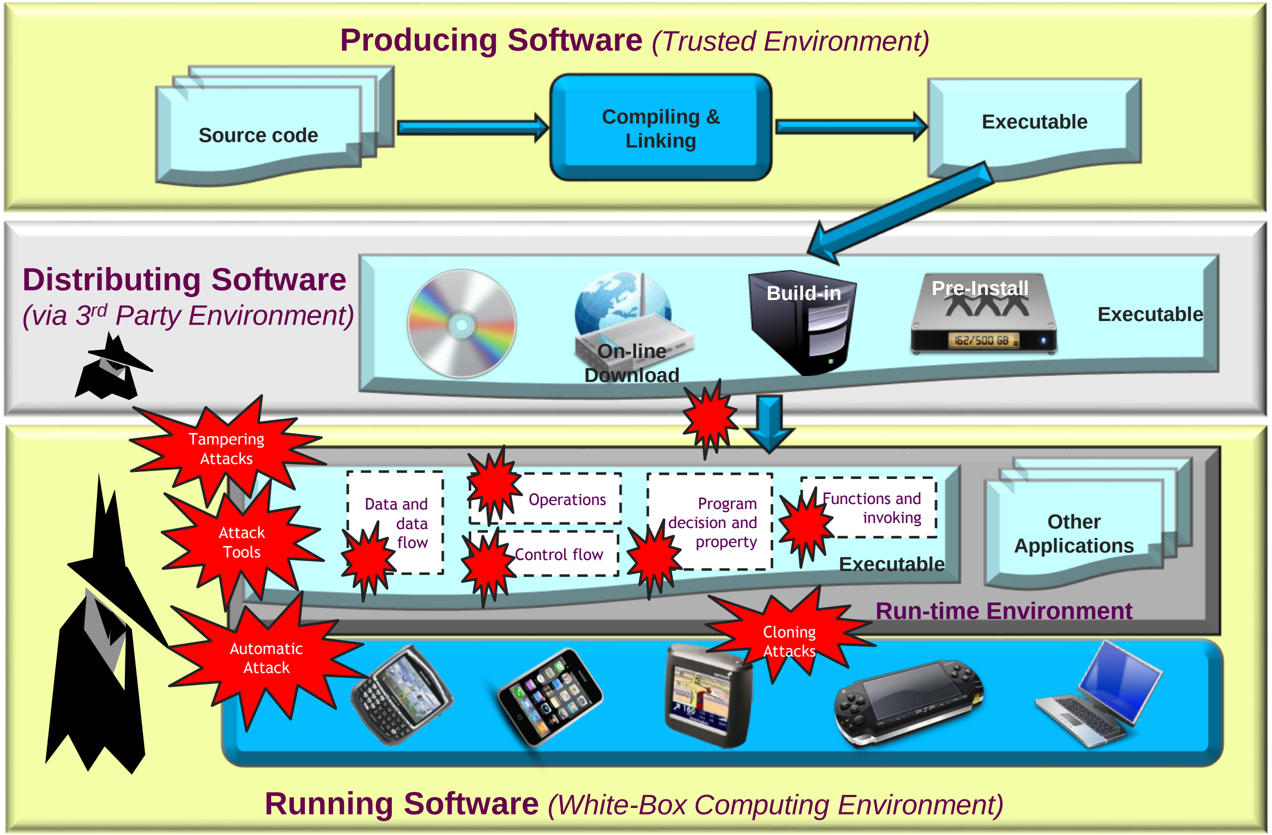
WhiteBox Security Patterns

- Abstract and define white-box computing problems (vulnerabilities, threats and attacks) and establish the security solutions that defend against them
  - Develop a small and finite set of WB computing security patterns
  - Easy to understand and adapt in real world
- Create a new common language for software security and protection to
  - Provide an effective tool to promote software protection technology
  - Provide a foundation for software protection evaluation model and methods.
  - Make it much easier to engage the wider academic community, generate more research attentions and create generic mindshare
- As a reference used by security professionals and ultimately would become the secure application guidelines
  - The security patterns should be used to create a set of security architecture and design guidelines to the security professionals and security system designers

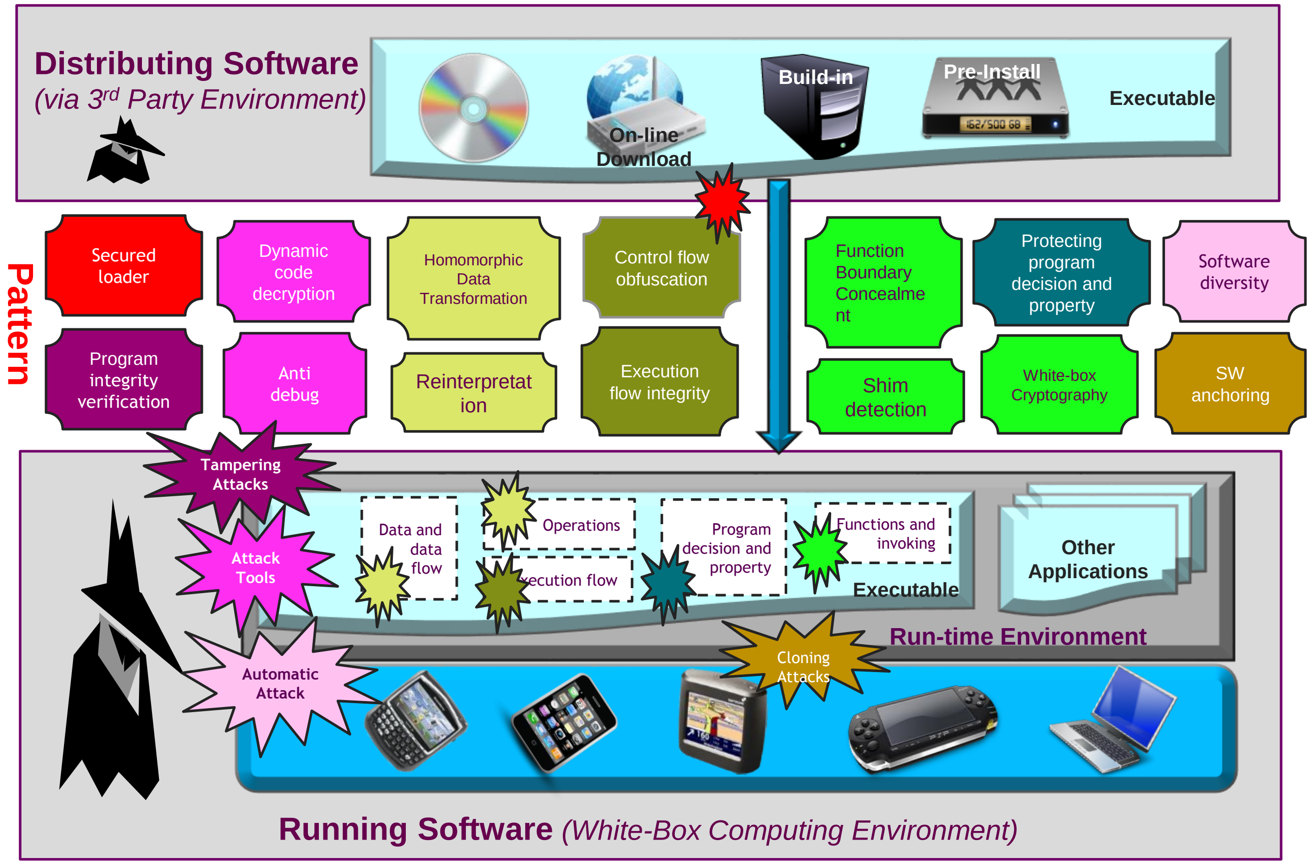
White-Box Security Patterns: Present & Future



Direct Attack Points (Just Examples)



WB Security Pattern Coverage



Well Understood WB Security Patterns

irdeto

- **Primitive Patterns**

Pattern 1:	**Homomorphic data transformation**
Pattern 2:	Protecting program decision and property
Pattern 3:	Function boundary concealment
Pattern 4:	Control flow obfuscation
Pattern 5:	**Execution flow integrity**
Pattern 6:	**White-Box cryptography**
Pattern 7:	**Program integrity verification**
Pattern 8:	Anti-debug
Pattern 9:	Secure loader
Pattern 10:	Dynamic code decryption
Pattern 11:	SW anchoring

- **Abstract Patterns**

Pattern 12:	Software diversity

- **Derived Patterns**

Pattern 13:	Reinterpretation
Pattern 14:	Shim detection

Description in Details for Four White-Box Security Patterns

WB Security Patterns

- **Primitive Patterns**

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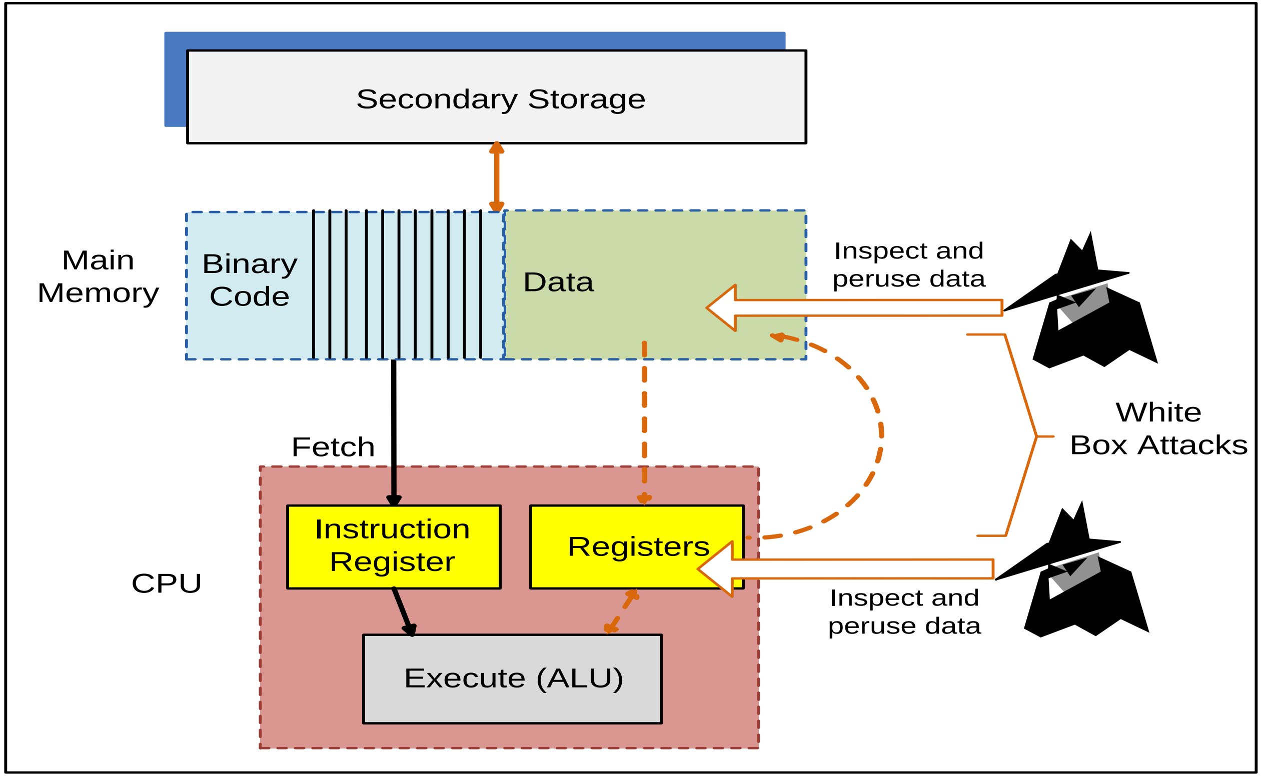
Homomorphic Data Transformation:
Security Context



Homomorphic Data Transformation:
Security Problem

- At runtime, data frequently exists in a program or file in various classes of storage for white-box exposure:
  - In registers
  - on the stack, the heap or disk
  - other forms of secondary storage etc
- Computable data stored in different storage forms or transferred from different sources may have different vulnerabilities, but a contributing factor common to them is the well-known layout of data while they are processed by a program

Homomorphic Data Transformation:
Security Problem (2)

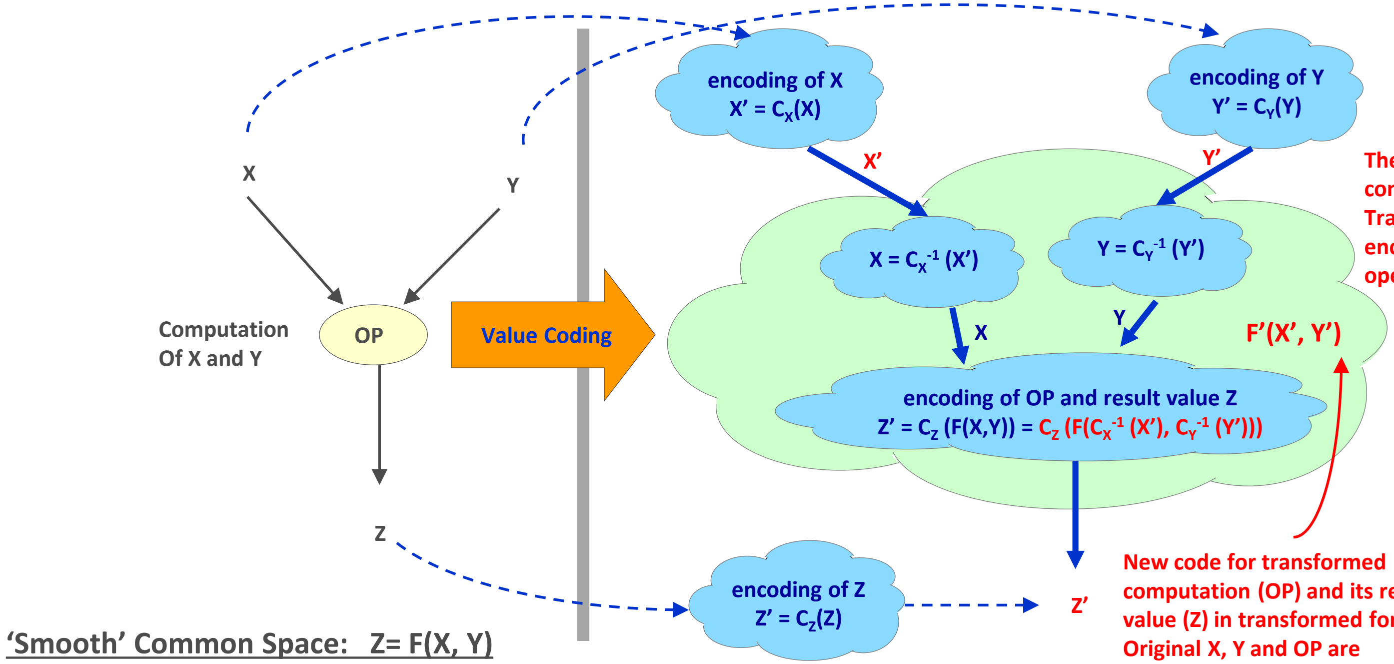
- Data can be transferred dynamically via network connections to local device so that they can be accessed by local program
- Once the attacker reaches a data asset, that asset succumbs completely because the data is stored using conventional formats
- The attacker will know how to discern the object’s value and assign to it a properly hacked value
- These kinds of storage technology normally have little protection against white-box attacks

Homomorphic Code/Data Transformation are Essential

- Modern computer systems provide an open & common computation space
- Computational data is a crucial asset needing protection
- Both the original values of computational data, and the computations on it, must be hidden to
  - Protect against reverse-engineering and subsequent code compromise
    - Using static tools such as program analyzers, binary editors and disassemblers
    - Using dynamic tools such as debuggers, logic analyzers and emulators

Transforming of data, computations and data flow is an essential first step in HO

Homomorphic Data Transformation: Principle



The implementation computes in the Transformed Space without encoding/decoding operations.

The green blob is a homo-morphism with 3 connecting encodings (for 2 inputs and 1 output). Multiple distinct homomorphic blobs connect at the I/O points, making the obfuscated code a *homomorphic network.*

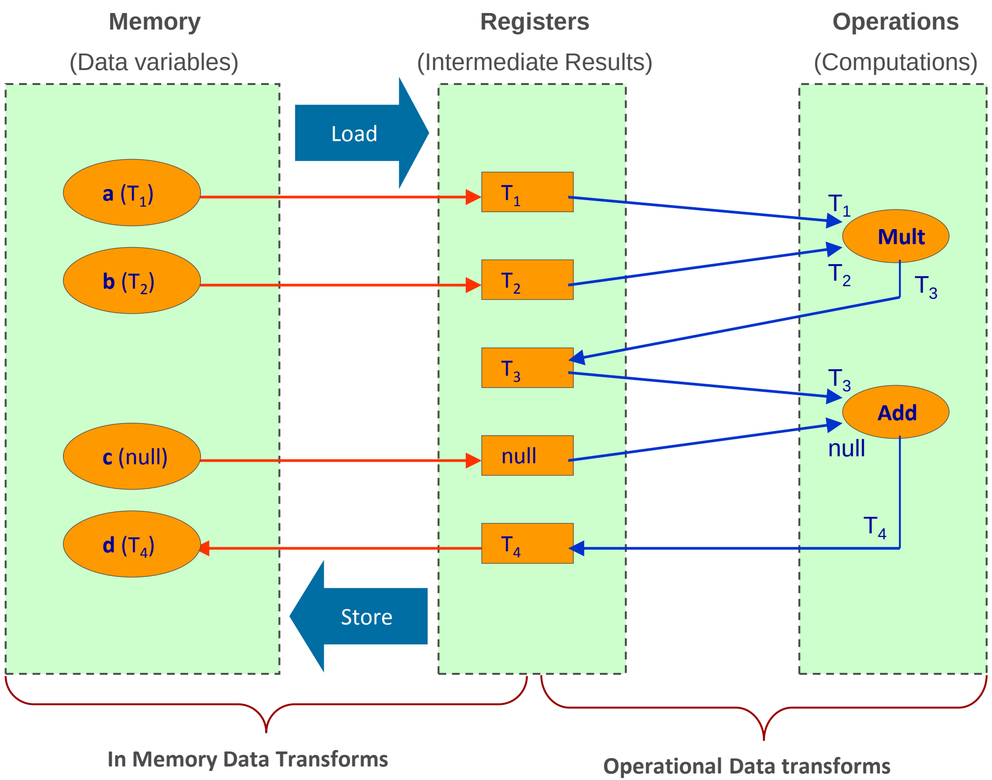
New code for transformed computation (OP) and its result value (Z) in transformed form. Original X, Y and OP are disappeared.

Original data flow

Cloaked data flow

Relationship between smooth and transformed value

Homomorphic Data Transformation: in Memory and Operations



User can select transformations or preserving by using setting

Transform Applicability

Case	Memory	Register	Operation
1	T	T	T
2	null	T	T
3	null	null	T
4	null	null	null
5	T	T	null
6	T	null	null
7	T	null	T
8	null	T	null

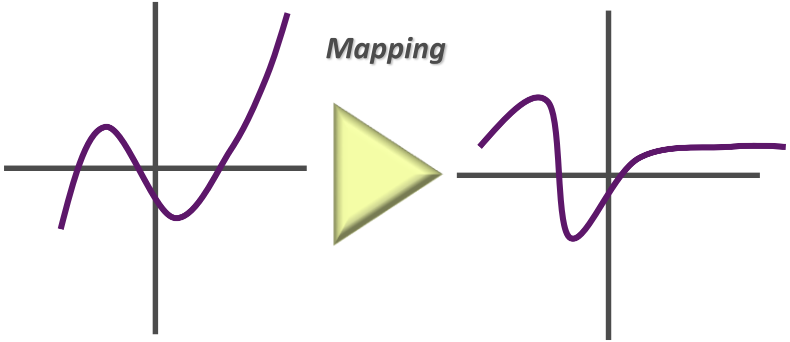
Recommended use of transforms

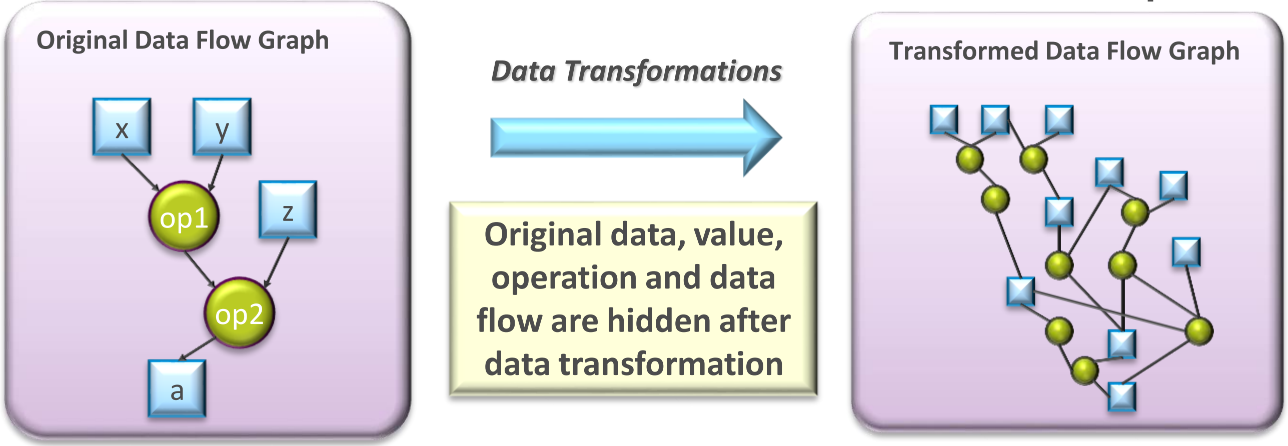
Applicable cases

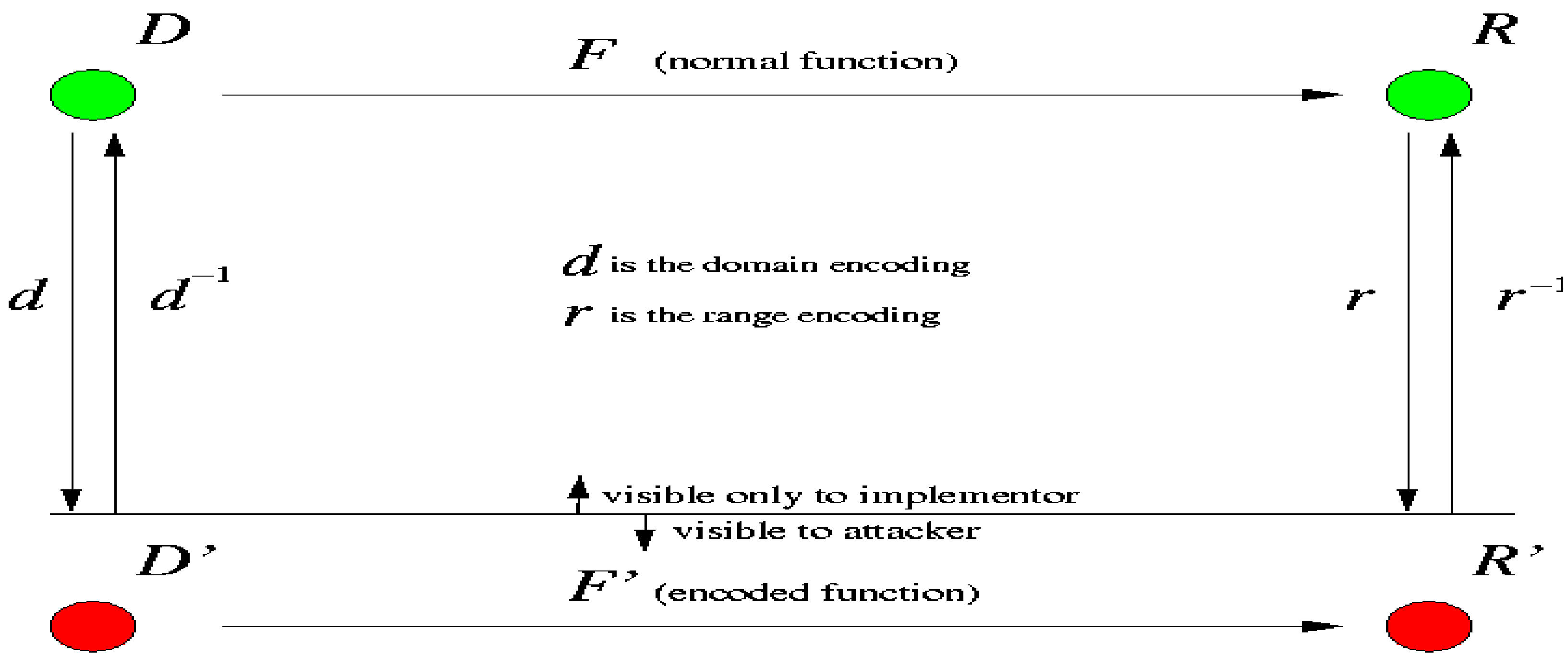
Avoided cases if possible

Homomorphic Data Transformation: In General

- Mathematical transformations on
  - Data Values
  - Data Locations
  - Data Operations
- Many Transform Families
- Randomness
- Random seeds support repeatability
- Must balance security vs. performance to fit the application







Homomorphic transformation of data and computation space is fundamental to homomorphic obfuscation irdeto

- ***Many to many mappings*** between original and transformed data and code make reverse engineering difficult

  (*NP-complete fragment recognition problem*)

	Sample 1	Sample 2	Sample 3	Sample 4
Original code segment	z = x + y	z = x + y	z = 2x + y	z = x + 5
Transcoder transforms	x' = 5x +7 y' = 5y + 10 z' = 5z + 17	x' = 5x +7 y' = -10y + 10 z' = 10z + 4	x' = 5x +7 y' = -5y +11 z' = 5z + 3	x' = 5x +7 z' = 5z -18
Transformed code segment	z' = x' + y'	z' = 2x' – y'	z' = 2x' – y'	z' = x'

WB Security Pattern

- **Primitive Patterns**

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- **Abstract Patterns**

Pattern 12:	Software Diversity

- **Derived Patterns**

Pattern 13:	Reinterpretation
Pattern 14:	Shim detection

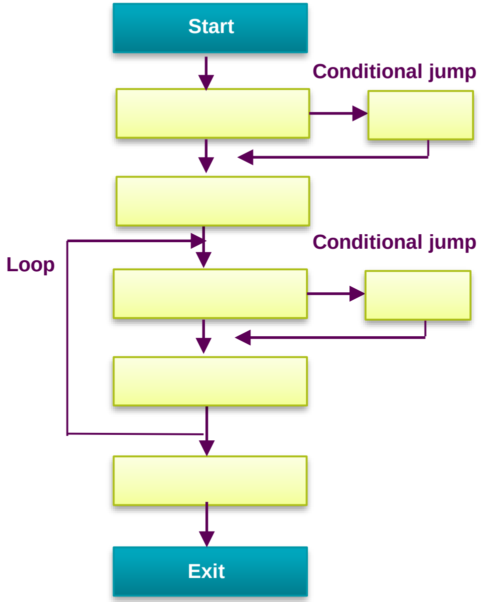
Execution Flow Integrity:
Security Context and Problem

- Basic blocks are primary components of program execution flow. Flow dependency between those basic blocks is statically fixed.
- Control flow obfuscation provides only for hiding the original intent of the control flow, but cannot guarantee execution flow integrity
- The protection of execution flow of a function requires to resolve the following two problems:
  - Transform control flow and make the control flow hard to be analyzed and extracted statically and dynamically.
  - Transform execution flow of a function so that the flow cannot be tampered easily and can be detected and mitigated if it is tampered

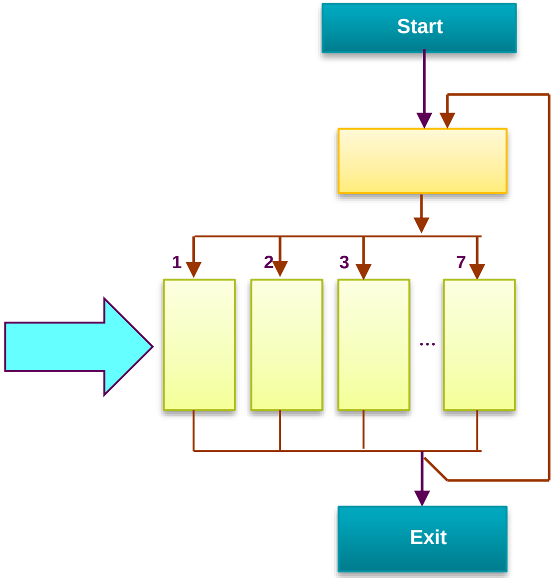
Execution Flow Integrity:
Security Intent

- Extend original execution flow with history dependency based on original execution order of a function
  - For each particular flow from one basic block to another block, inject a pair of encode and decode and necessary temporary variables to interlock the flow
  - The original control-flow is transformed into a data directed control-flow by injected history dependency
  - The extended execution order is no longer static and must be determined at run-time by the computation of history dependency relationship
- Data transformation can be used to protect the history dependency computation
- Any tampering attack to history dependency will result wrong execution flow

Execution Flow Integrity:
Solution – Control Flow Flattening

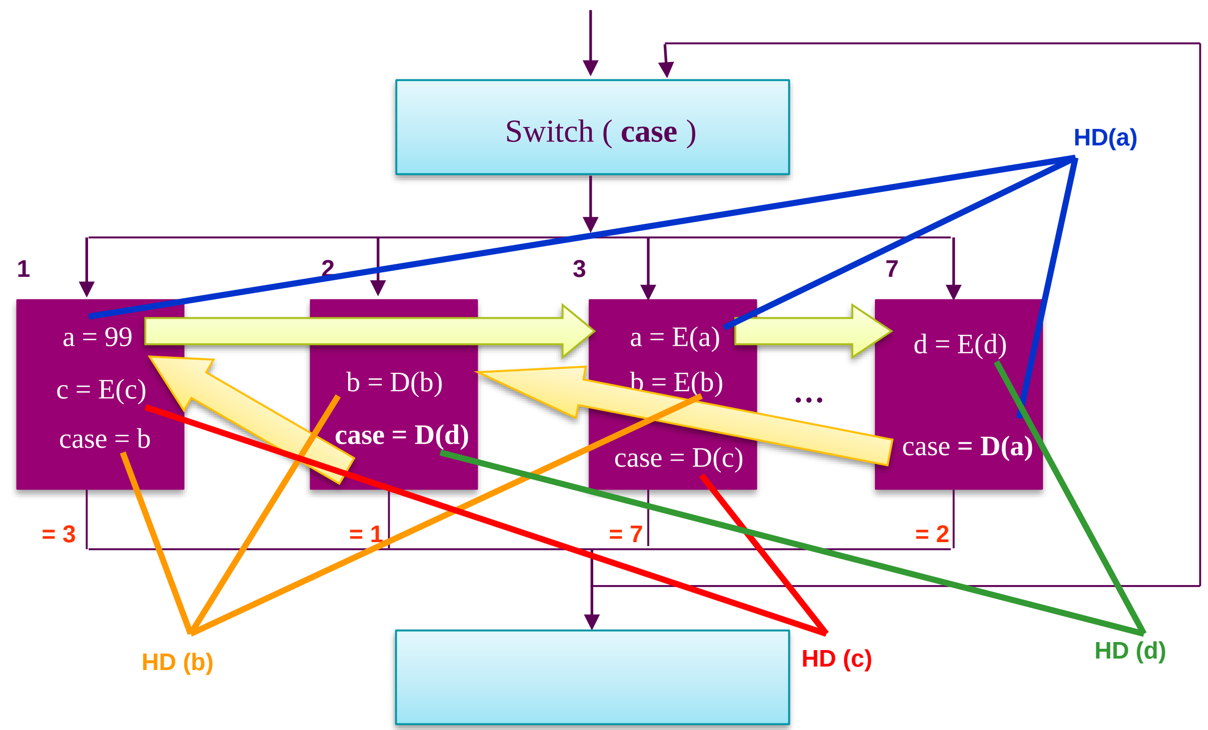


Original Program Flow



Control Flow Flattened Program

Execution Flow Integrity: Solution - History-Dependent Transforms



WB Computing Security Pattern

- **Primitive Patterns**

Pattern 1:	Homomorphic data transformation
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- **Abstract Patterns**

Pattern 12:	Software Diversity

- **Derived Patterns**

Pattern 13:	Reinterpretation
Pattern 14:	Shim detection

White-Box Cryptography: Security Context – Cryptography Is Used Everywhere

Modern cryptography is one of most fundamental technology adopted for traditional security problems.

Art

Solid Security Primitives and Protocols

Cryptography Past 90 years

Science

White-Box Cryptography: Security Context – Cryptography Is Used Everywhere

- For applications that run in a hostile environment, cryptographic keys and other valuable assets become much easier and common attack targets for a multitude of purposes than in a trusted environment

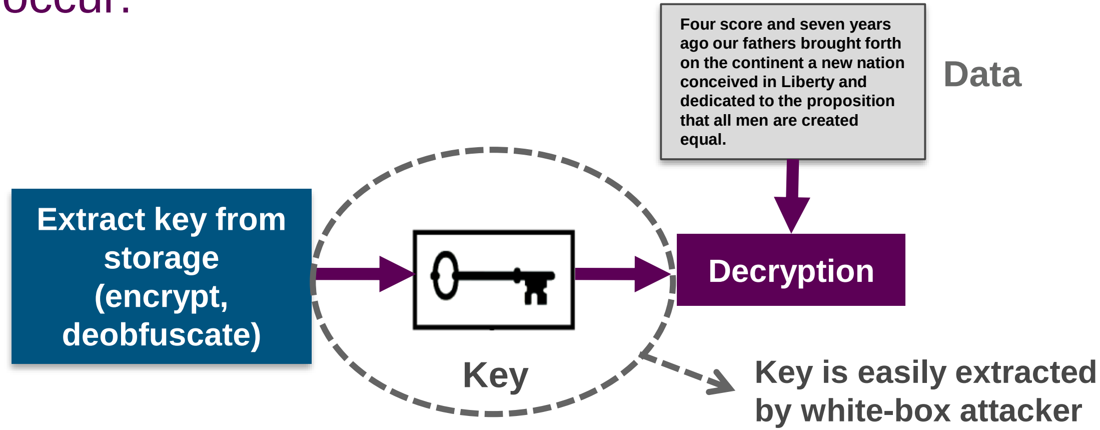
- In most business models, the recovery of some or all of these keys directly threatens the revenue from the applications, services, or digital assets

White-Box Cryptography:
Security Context – Cryptographic Dilemma

- Cryptographic algorithms are well known to attackers because they are standards-compliant algorithms and well deployed by information systems (i.e. AES, RSA, ECC, SHA1).
- Whitebox context requires much more severer security challenges than traditional crypto attacks such as to black-box and side-channel attacks
  - any attack that can be mounted through the side-channel can be mounted more effectively via a direct channel
  - the information the side channel reveals can always be revealed through a direct channel as well
  - black-box crypto security does not work for white-box context

White-Box Cryptography:
Security Problem – Key and Valuable Assets

- Software keys can be
  - generated using high-quality pseudo random number generators (PRNG)
  - securely stored
- Sooner or later the key is ***used*** and the following events occur:



White-Box Cryptography:
Security Problem – White-Box Crypto Security

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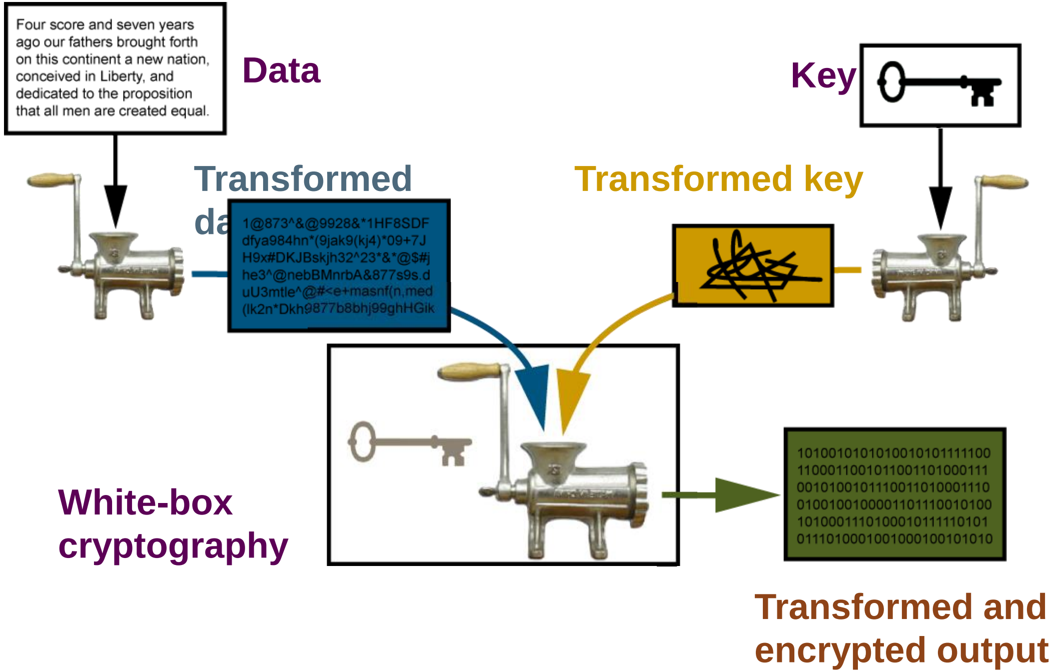
Existing cryptographic security proofs from the black-box and grey-box attack context simply don't carry over to the white-box context. ***It is broken!***

- We are now forced to defend against white-box attackers who are strictly more powerful than classic black-box and grey-box attackers
- How can a secret key be used in a cryptographic algorithm without being exposed in the context in which it is attacked in white-box fashion?

White-Box Cryptography:
Security Intent

- The fundamental security intent of white-box cryptography is to make the recovery of the key in the whitebox context at least as difficult, mathematically, as in the black-box context
- Stated in another way, this pattern is to transform a key such that attacking within the whitebox context offers no advantage to attacking in the black-box context
- Black-box cryptographic security can be truly guaranteed within white-box context and even improved further if possible

White-Box Cryptography Applies Homomorphism

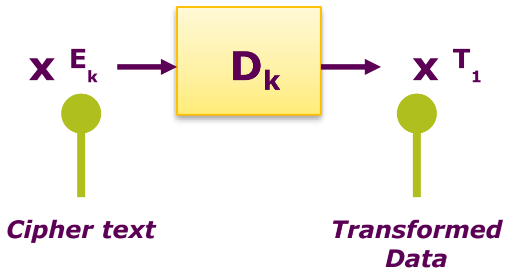


- White-box cryptographic methods use homomorphic transformations
- White-box cryptography ensures that input data, keys, intermediate results and output data are protected at all times by using homomorphic transformations

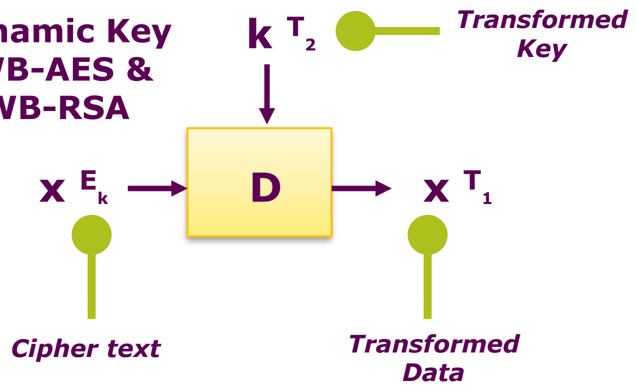
White-Box Cryptography:
Solution - White-Box Ciphers (examples)

- **AES and RSA algorithms**
  - AES-128bit / AES-256bit
  - RSA-1024bit to RSA-4096bit
  - WB-EC-DSA (sign, verify) standard NIST curves
- **Fixed Key WB-AES, WB-RSA and WB-EC-DSA**
  - Key is fixed and embedded in WBAES lookup tables
- **Dynamic Key WB-AES and WB-RSA**
  - Key is generated/supplied at runtime and transformed using data flow transformations

Fixed Key WB-AES, WB-RSA and WB-EC-DSA



Dynamic Key WB-AES & WB-RSA



White-Box Cryptography:
Solution - WB Implementation

- The key is mathematically inseparable from the surrounding data in which it's been evaluated and embedded
  - Keeps a key hidden even if the attacker has visibility of the executing program
  - Increases the difficulty of key extraction
- The transformed key can be evaluated by an algorithm that may be different from the original cryptographic operation but that yields the same result as the published algorithm with the same input data
- WB ciphers can leverage data transformations to ensure that inputs to and outputs from white-box crypto operations do not appear in the clear
- Moreover, all transformed inputs, keys and outputs can be involved transformed computations before and after a white-box crypto operation.

WB Security Patterns

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- **Primitive Patterns**

Pattern 1:	Homomorphic Data Transformation
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Program Integrity Verification:
Security Context

- The modification of application code and data is a common attack against application software
- The user and environment, which the application is running in, are untrustworthy
  - The user or environment could modify the application
  - The application cannot rely on its environment to report or protect against code and data tampering attacks
- There are a wide variety of freely available tools to allow an attacker to easily modify an application either statically or dynamically.
- These tools may include hex editors, debuggers, disassemblers and tracers.

Program Integrity Verification:
Security Problem

Static or dynamic code & data tampering can provide an attacker with the ability to modify the execution of the application resulting in

- An undesired behavior
- Escalating unauthorized privileges.
- Circumventing or breaking the copy protection on the application

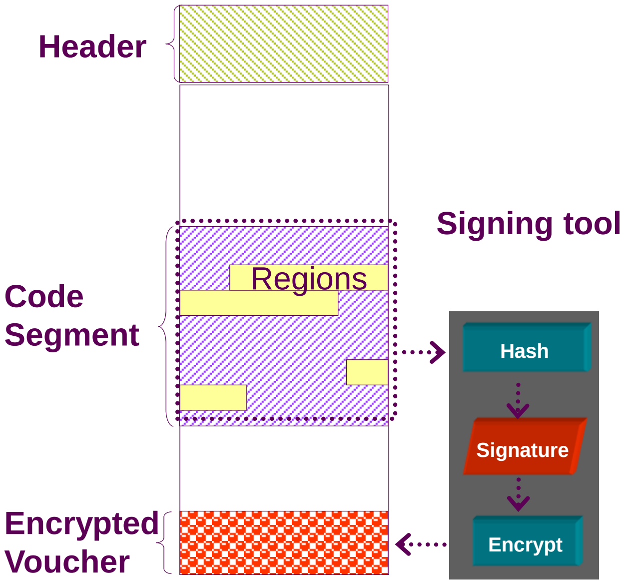
Program Integrity Verification:
Security Intent

- Program integrity verification is a kind of tampering resistant techniques to detect and react to tampering of an applications code and data
- Integrity verification of program image and data files on disk
  - Module level (executable, dynamic share libs, other binary and data files)
- Integrity verification of program binary in memory
  - Binary code
    - Module level (executable, dynamic share libs)
      - Single Module or multiple modules
    - Smaller fine grain level

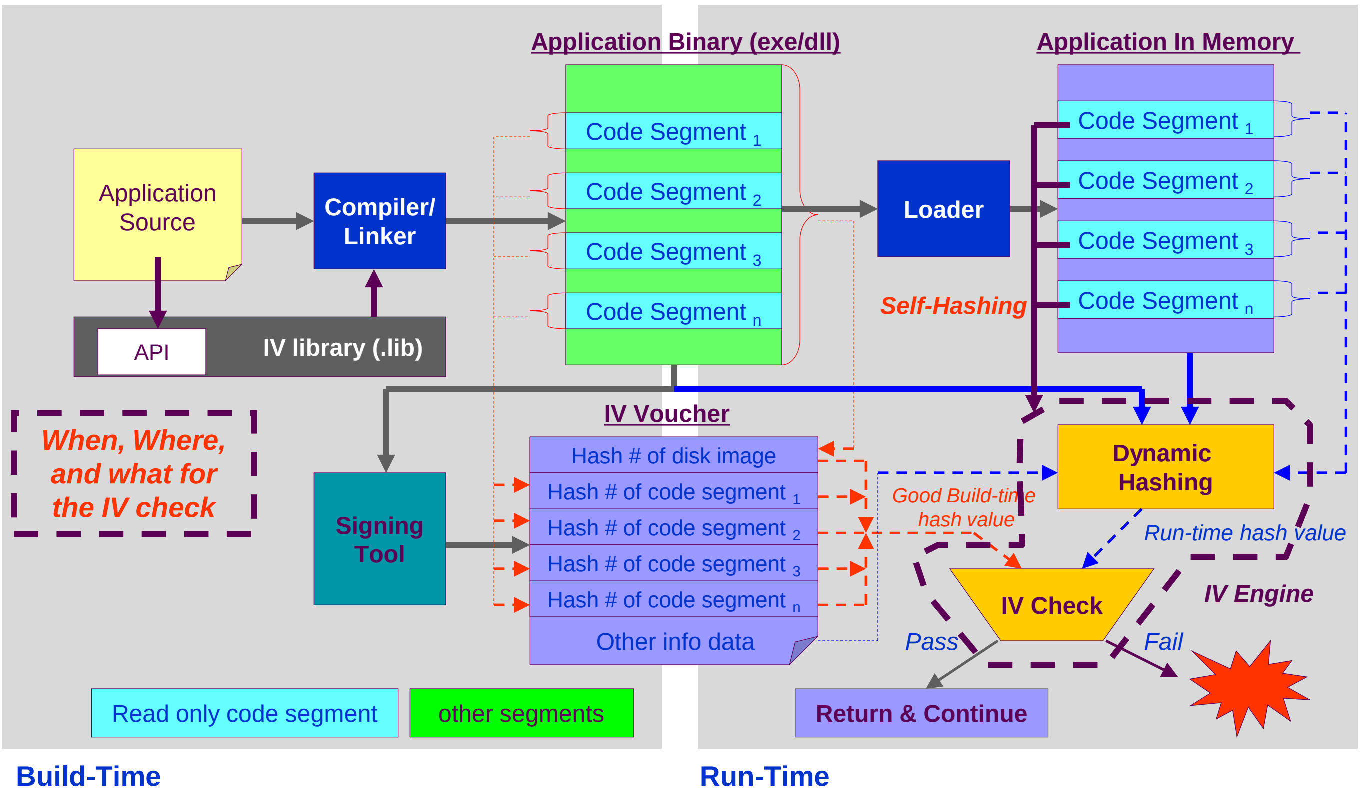
      a) Function level; b) Basic block level; c) Instruction level
  - Global constants
  - Export table of dynamic share libs

Program Integrity Verification:
Solution – Signing Process at Build-time

- "On Disk" API function call verifies the entire file integrity
- "In Memory" API function call verifies portions of the code segment residing in memory
- Code Segment is partitioned into regions to speed up integrity checks
- Hash segments contain several interoperable regions
- Run-time Decryption for IV data uses White Box Crypto



Program Integrity Verification:
Solution – Self-hashing IV Technique



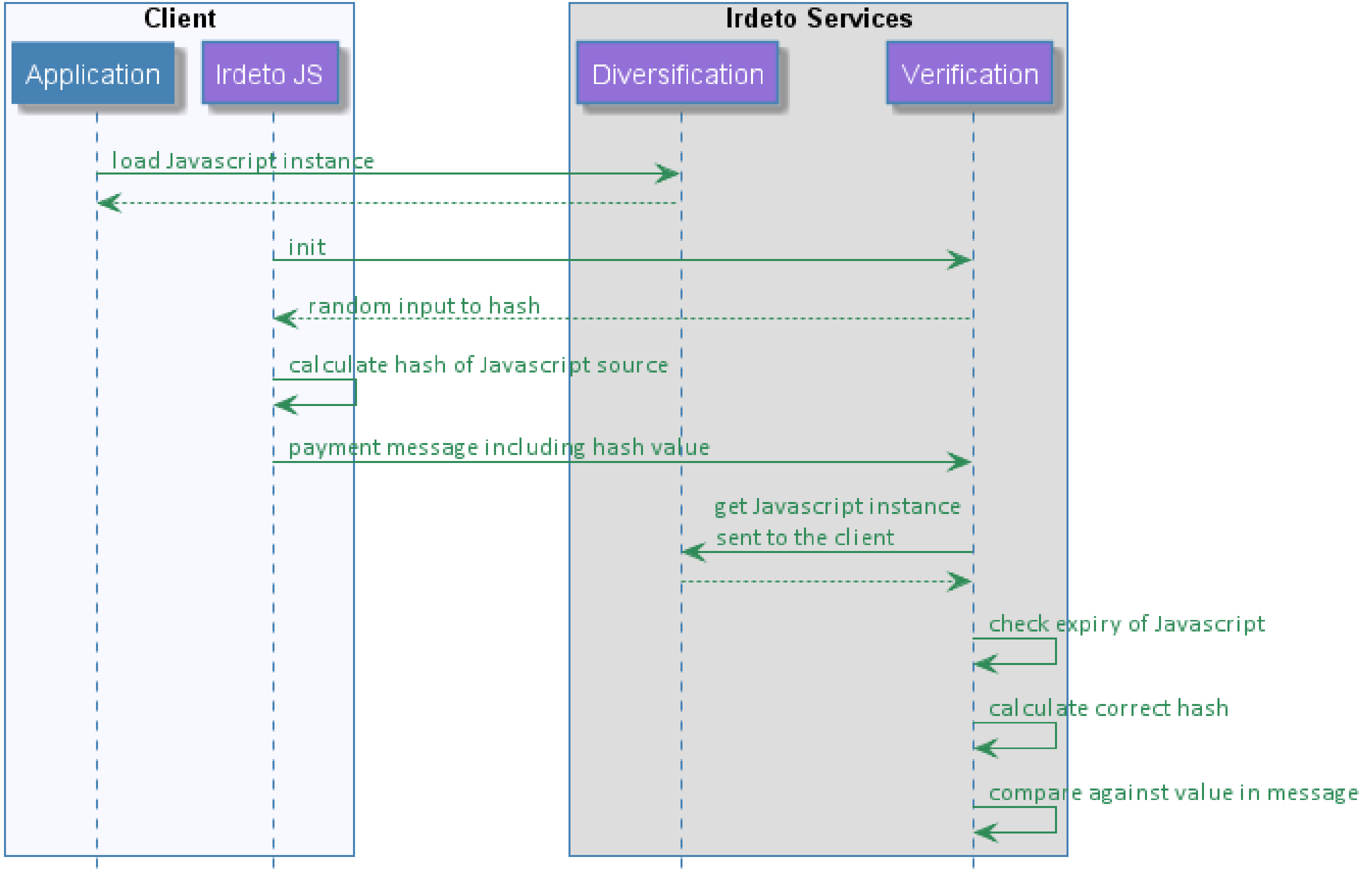
Server based JS Integrity Verification

- The Integrity Verification is a server-side check which detects if the secure Javascript is being changed

1. Javascript source in the DOM or name space is hashed by the browser.
2. The hash value is sent to a server component
3. The server checks that the hash value matches the expected value for the specific Javascript instance

- Each Javascript instance uses a different key for the HMAC
- IV is a challenge-response mechanism. Data from the server provides randomness to the hash values calculated to prevent replay attacks

Integrity Verification



Runtime Verification

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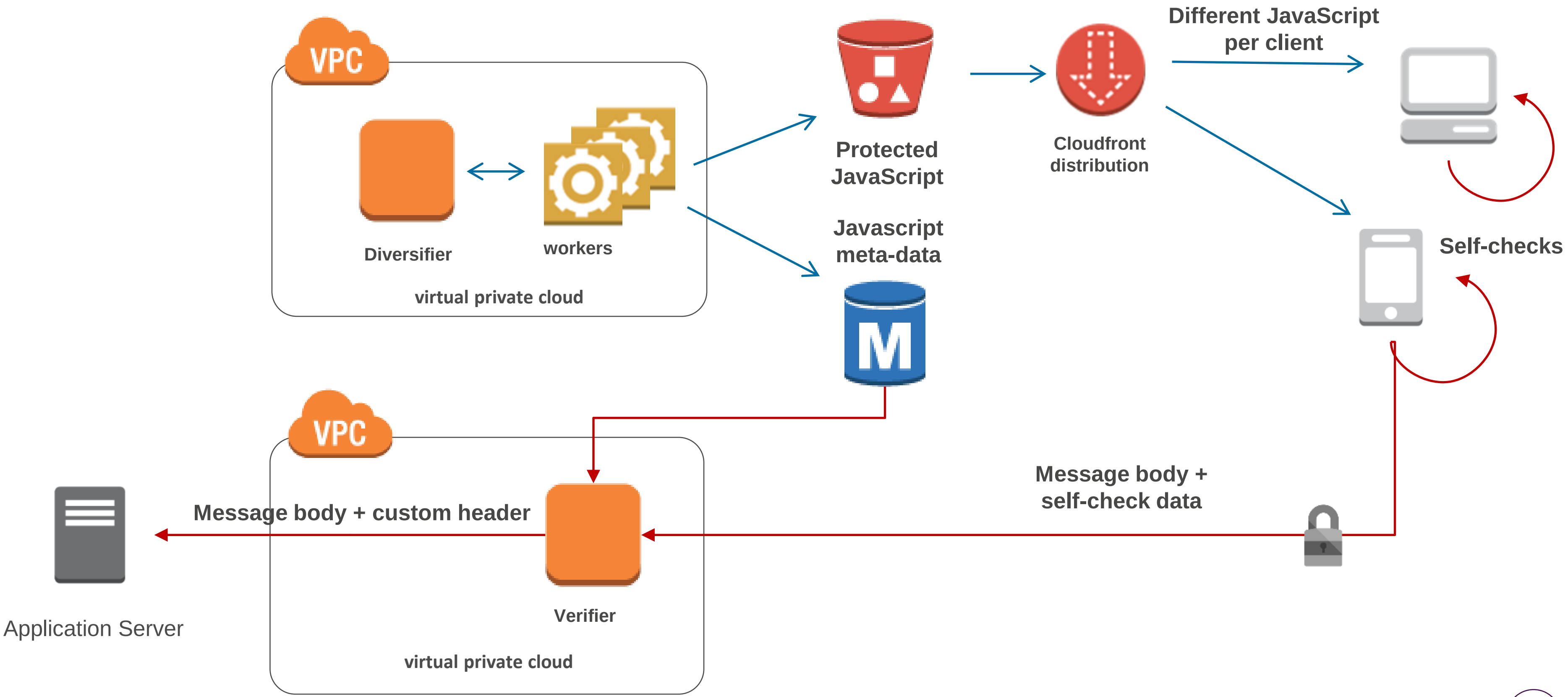

Summary

- Black-box and grey-box security models are inadequate for many important software applications
- We need more research into creating software that is secure in the white-box attack model
- White-Box attacks are much more difficult security problems
- White-Box security is a new challenge for both industrial and academic communities
- Software security needs software protection solutions and methods across the security lifecycle
- Software protection is a very young field and many open problems are new opportunity for talent students and researchers to resolve
- Irdeto is a leader in digital asset protection technology with considerable uptake worldwide
- Research collaboration and internship with Irdeto are encouraged

Question?

Thanks!

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