CYBSEC SA
Security Systems

Attacking the Giants: Exploiting SAP Internals

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Agenda

- SAP Connectivity
- SAP RFC Interface
- The RFC Library
- Security Review of the RFC Interface Implementation
- Advanced Attacks
- Tool Release: sapyto
- Conclusions
- Questions & Answers

SAP Connectivity

SAP Connectivity

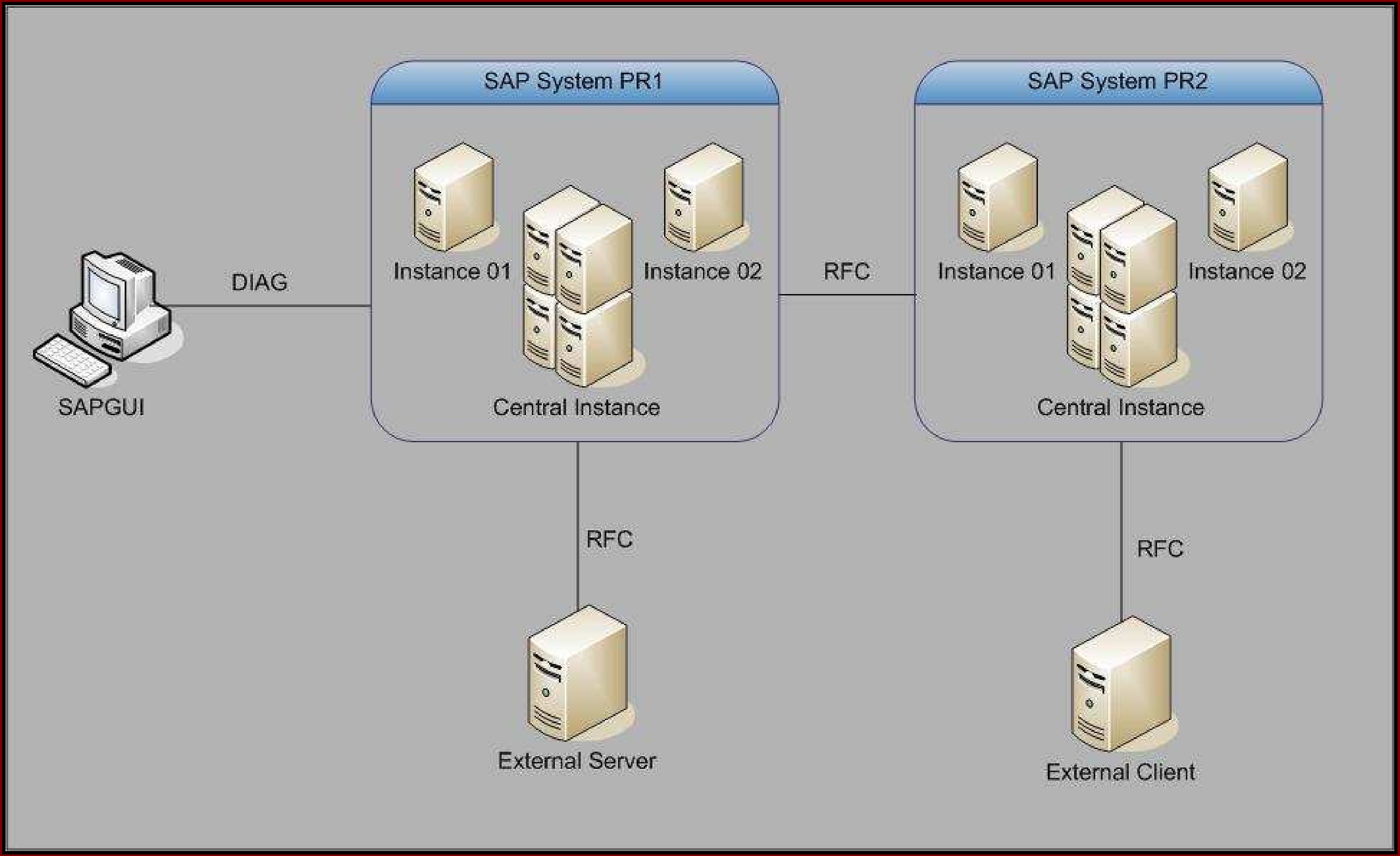
- SAP is designed to be able to interact with many external systems.
- This way you can integrate and centralize information under a unique architecture.
- Communicating with other systems:
  - ALE
  - EDI
  - HTTP
  - RFC
  - FTP
  - XML
  - …

SAP RFC Interface

A Bit of History...

- In the beginning, SAP implemented IBM´s CPI-C interface to communicate with other systems.
- CPI-C was developed to allow data transfer.
- Complex applications needed to be able to call functions on other servers.
- Result: SAP Remote Function Call (RFC) Interface.
- Developed in the 1980s, based on CPI-C.
- Today, the RFC Interface is a key component of the SAP Application Server.

SAP Systems Layout



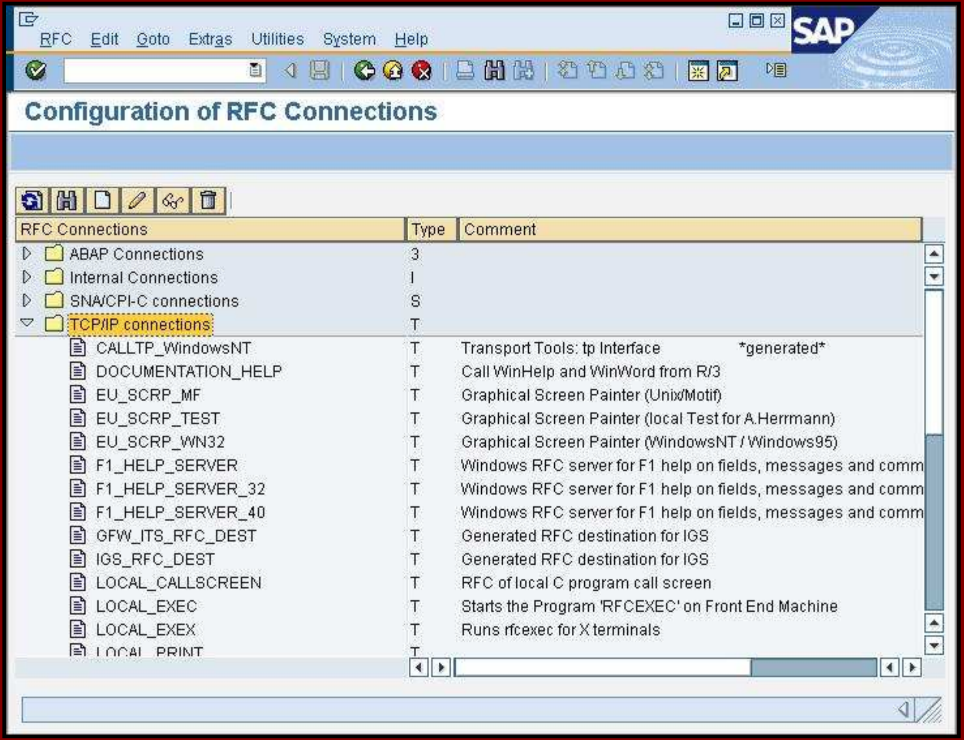
RFC Between SAP Systems

- For a Function Module to be remotely-callable, it must be flagged as "Remote-enabled".
- ABAP Programs call a remote Function Module using the command CALL FUNCTION…DESTINATION..

```
...
CALL FUNCTION ‘ZCUST_GETMONEY’ DESTINATION ‘PROD2’
        EXPORTING
                ZCUST_ID = 100
        IMPORTING
                MONEY = cust_money
        TABLES
                TABINFO = table1
        EXCEPTIONS
                CUST_NOT_FOUND = 0
                TABLE_EMPTY = 1
...
```

RFC Between SAP Systems

- The DESTINATION parameter notifies the AS that it is a remote call.
- Specifically, DESTINATION is a index key to a RFC Destinations table (RFCDES), maintained through transaction SM59.

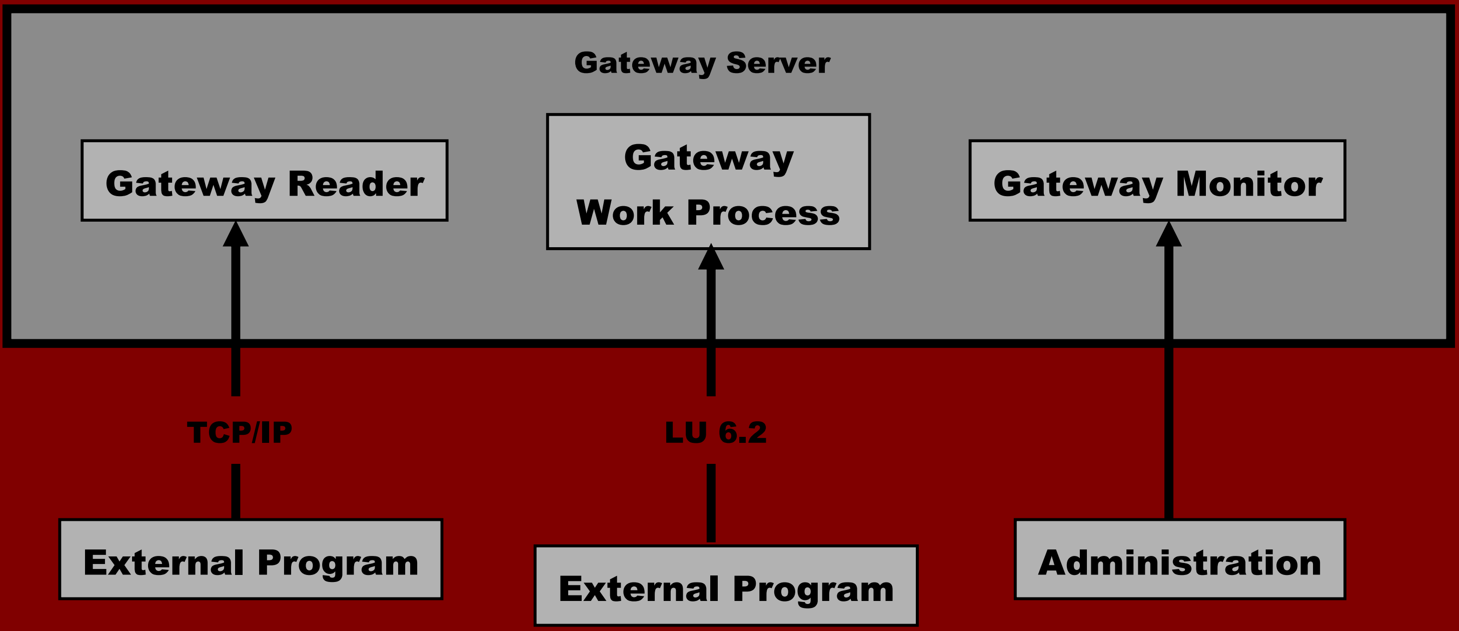


Configuration of RFC Connections

RFC Connections	Type	Comment
ABAP Connections	3	
Internal Connections	I	
SNA/CPI-C connections	S	
TCP/IP connections	T	
CALLTP_WindowsNT	T	Transport Tools: tp Interface *generated*
DOCUMENTATION_HELP	T	Call WinHelp and WinWord from R/3
EU_SCRP_MF	T	Graphical Screen Painter (Unix/Motif)
EU_SCRP_TEST	T	Graphical Screen Painter (local Test for A.Herrmann)
EU_SCRP_WN32	T	Graphical Screen Painter (WindowsNT / Windows95)
F1_HELP_SERVER	T	Windows RFC server for F1 help on fields, messages and comm
F1_HELP_SERVER_32	T	Windows RFC server for F1 help on fields, messages and comm
F1_HELP_SERVER_40	T	Windows RFC server for F1 help on fields, messages and comm
GFW_ITS_RFC_DEST	T	Generated RFC destination for IGS
IGS_RFC_DEST	T	Generated RFC destination for IGS
LOCAL_CALLSCREEN	T	RFC of local C program call screen
LOCAL_EXEC	T	Starts the Program 'RFCEXEC' on Front End Machine
LOCAL_EXEX	T	Runs rfcexec for X terminals
LOCAL_PRINT	T	

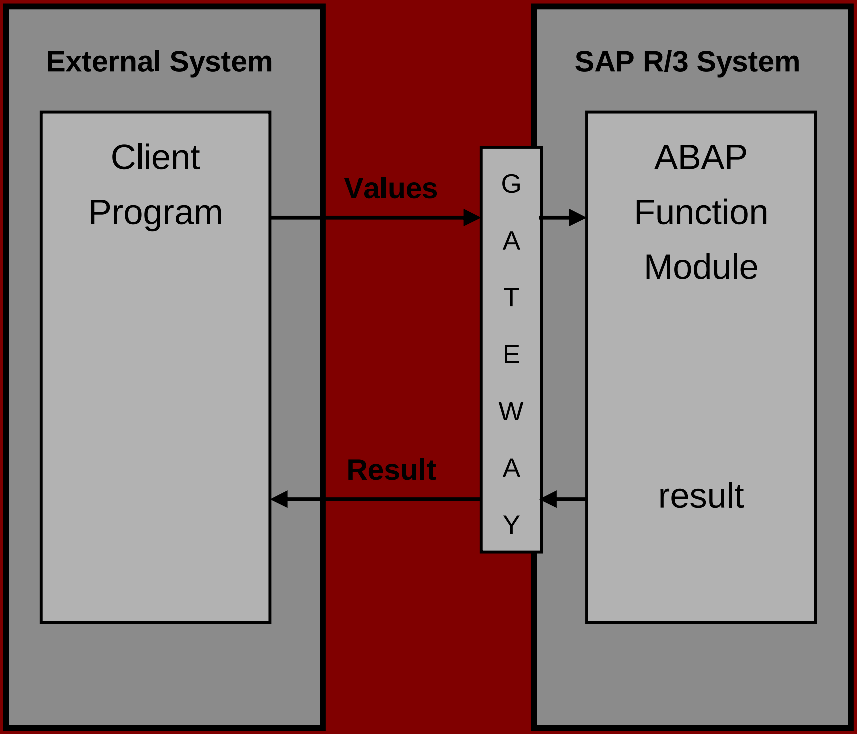
The Gateway Server

- Communication is done through the Gateway Server.
- Handles communications between SAP systems and between SAP systems and External systems.
- Logically, it consists of three different services.

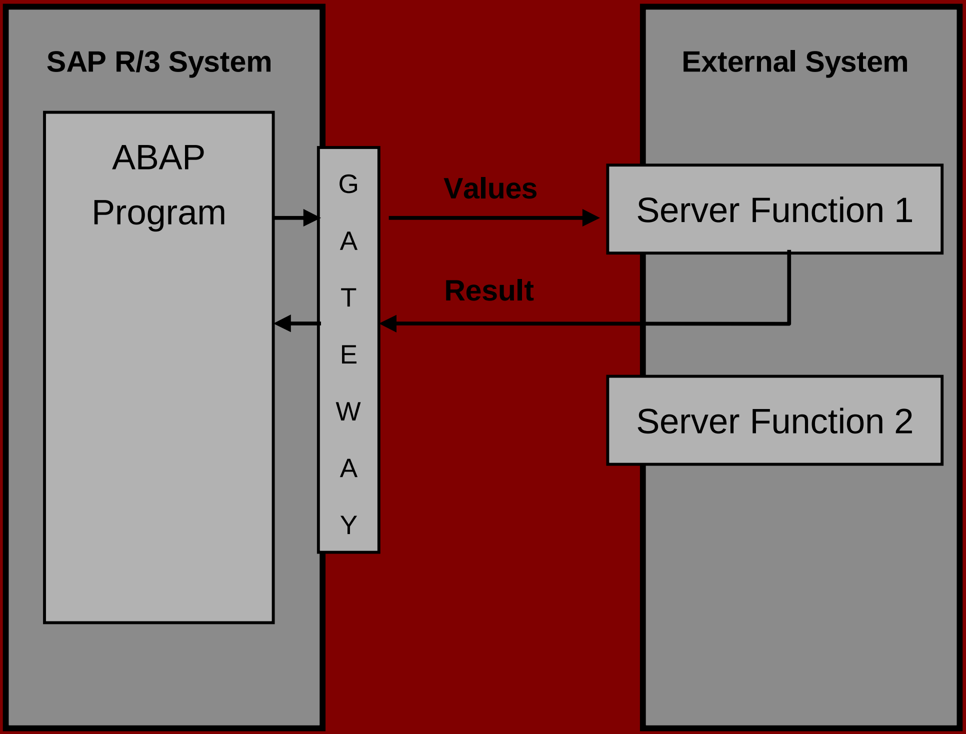


RFC Between SAP and External Systems

- External RFC Client



- External RFC Server



External RFC Servers

- By "default", client doesn't need to supply logon information.
- 2 Ways of "attaching" External RFC Servers:
  - Started Mode
    - Application Server starts them remotely on-demand.
    - Commonly via Remote Shell or Remote Exec (!)
    - External Server is closed after operation.
  - Registered Mode
    - External Server registers at the Gateway Server.
    - Identified by a Program ID.
    - External Server is not closed.

But … How do you develop an external client / server ??

The RFC Library

The RFC Library

"The RFC Library is the most commonly used and installed component of existing SAP software"

SAP RFCSDK Guide

- API released by SAP to allow development of external clients/servers.
- Available for all SAP supported platforms.
- Forward, backward and sideward compatible.
- An upper layer: JCo, .Net, …
- Very good documentation.
- Delivered with examples.

External RFC Server Internals

- First of all, the server install available functions:

```
RfcInstallFunction(RFC_FUNCTIONNAME functionname,
                   RFC_ONCALL f_ptr,
                   rfc_char_t *docu);
```

- Listen and dispatch requests with RfcDispatch() loop.
- Requested function (*f_ptr*) is executed.
- Results are sent back to client.
- Three functions installed by default:
    - RFC_DOCU
    - RFC_PING
    - RFC_SYSTEM_INFO

Security Review of the RFC Interface Implementation

Traffic Analysis

- Information is sent in clear-text by default.
- SAP provides SNC (Secure Network Communications) for encryption of traffic.
- What can we get?
  - Logon information.
  - Called Function Name.
  - Parameters Information and Content.
  - Tables Information and Content (may be compressed).
  - Client and Server information.
  - ...

Traffic Analysis

```
...
01a0   00 00 00 00 00 00 06 05 14 00 10 5f 22 ea 45 5e     ..........._".E^
01b0   22 c5 10 e1 00 00 00 c0 a8 02 8b 05 14 01 30 00     ".............0.
01c0   0a 72 66 63 5f 73 65 72 76 65 72 01 30 01 11 00     .rfc_server.0...
01d0   06 42 43 55 53 45 52 01 11 01 17 00 0b 81 bb 89     .BCUSER.........
01e0   62 fc b5 3e 70 07 6e 79 01 17 01 14 00 03 30 30     b..?w.oy......00
01f0   30 01 14 01 15 00 01 45 01 15 05 01 00 01 01 05     0......E........
0200   01 05 02 00 00 05 02 00 0b 00 03 36 34 30 00 0b     ...........640..
0210   01 02 00 0e 5a 43 55 53 54 5f 47 45 54 4d 4f 4e     ....ZCUST_GETMON
0220   45 59 01 02 05 14 00 10 5f 22 ea 45 5e 22 c5 10     EY......_".E^"..
0230   e1 00 00 00 c0 a8 02 8b 05 14 02 01 00 09 43 4c     ..............CL
0240   49 45 4e 54 5f 49 44 02 01 02 03 00 08 43 55 53     IENT_ID......CUS
0250   54 30 30 31 00 02 03 ff ff 00 00 ff ff 00 00 01     T001............
0260   c7 00 00 3e 80                                      ...>.
```

Traffic Analysis: Show me the Password!

- You said that data is clear-text… but I can't see a single password!
- Reason: Password is obfuscated.

```
for each CHAR in CLEAR_TEXT_PASS

       OBFUSCATED_PASS[i] = CHAR XOR KEY[i]
```

```
KEY_TO_THE_KINGDOM = [0x96, 0xde, 0x51, 0x1e, 0x74, 0xe,
0x9, 0x9, 0x4, 0x1b, 0xd9, 0x46, 0x3c, 0x35, 0x4d, 0x8e,
0x55, 0xc5, 0xe5, 0xd4, 0xb, 0xa0, 0xdd, 0xd6, 0xf5,
0x21, 0x32, 0xf, 0xe2, 0xcd, 0x68, 0x4f, 0x1a, 0x50,
0x8f, 0x75, 0x54, 0x86, 0x3a, 0xbb]
```

Function Analysis: RFC_DOCU

- Retrieves documentation about installed functions on External Server.
- Specifically, it outputs strings defined in the *rfc_docu* parameter of *RfcInstallFunction()* calls.
- No need for valid logon data.
- Available in External Systems.

This function can be used to discover installed functions and their structure.

Function Analysis: RFC_PING

- A RFC ping
- Connects to the target system, analyzing its availability.
- No need for valid logon data.
- Available in External Systems and R/3.

This function can be used to check for availability of remote RFC Server.

Function Analysis: RFC_SYSTEM_INFO

- Obtain RFC server system information.
- No need for logon data!
- Available in External Systems and R/3.

What can we get?

- SAP Kernel Version
- Hostname
- Timezone
- Database Engine
- Database Host
- SAP System ID
- Operating System
- …

Some Other Functions

There are other functions installed by default in every external RFC server. We have discovered security vulnerabilities in some of them:

- RFC_TRUSTED_SYSTEM_SECURITY
- RFC_SET_REG_SERVER_PROPERTY
- RFC_START_GUI
- SYSTEM_CREATE_INSTANCE
- RFC_START_PROGRAM

Any of this functions can be called, just as regular installed functions...

Function Analysis: RFC_TRUSTED_SYSTEM_SECURITY

- Designed for internal use by SAP only.
- Available in External Systems.

Impact:

This function can be used to check existence of users and groups in an External system, its domain and trusted domains.

Function Analysis: RFC_SET_REG_SERVER_PROPERTY

- Enables the definition of properties of External Registered Servers.
- Available in External Systems.

Impact:

Calling this function with a special parameter would render an External Registered Server unavailable to other clients (Denial of Service).

Function Analysis: RFC_START_GUI

- Starts SAPGUI on FrontEnd systems.
- Available in External Systems.

Impact:

Calling this function with a specially crafted parameter would result in the ability to run remote arbitrary commands over the External Server system.

Function Analysis: SYSTEM_CREATE_INSTANCE

- Enables the creation of remote objects, where an object adapter is available.
- Available in External Systems.

Impact:

Calling this function with a specially crafted parameter would result in the ability to run remote arbitrary commands over the External Server system.

Function Analysis: RFC_START_PROGRAM

- Enables the execution of programs on External Servers.
- Commands are restricted by the *RfcAllowStartProgram()* function:
  - No *RfcAllowStartProgram()* => Remote execution disabled
  - *RfcAllowStartProgram("foo.exe")* => Execution of "foo.exe" is authorized.
  - *RfcAllowStartProgram(NULL)* => All commands are authorized.

Function Analysis: RFC_START_PROGRAM (cont.)

Impact:

Calling the functions with specially crafted parameters would allow an attacker to:

- Obtain information about configuration of the remote server.
- Execute remote arbitrary commands, exploiting a buffer overflow vulnerability.

Function Analysis: RFC_START_PROGRAM (cont.)

What happens if *RfcAllowStartProgram("dumbprogram.exe")* ?

- Analysis of *RfcAllowStartProgram()* revealed that only the first N bytes of incoming program are verified, where N is the length of the allowed program.

- You know an allowed program, you can execute another:

  "dumbProgram.exe\..\..\..\path\to\evil\program.exe"

- According to SAP, external server developers should validate against this type of attacks...

RFCEXEC

- Bundled with the RFCSDK.
- Released as an example.
- Not intended for productive use.
- Installs the following functions:
  - RFC_RAISE_ERROR
  - RFC_MAIL
  - RFC_REMOTE_PIPE
  - RFC_REMOTE_FILE
  - RFC_REMOTE_EXEC
- Protected through *rfcexec.sec* file directives.

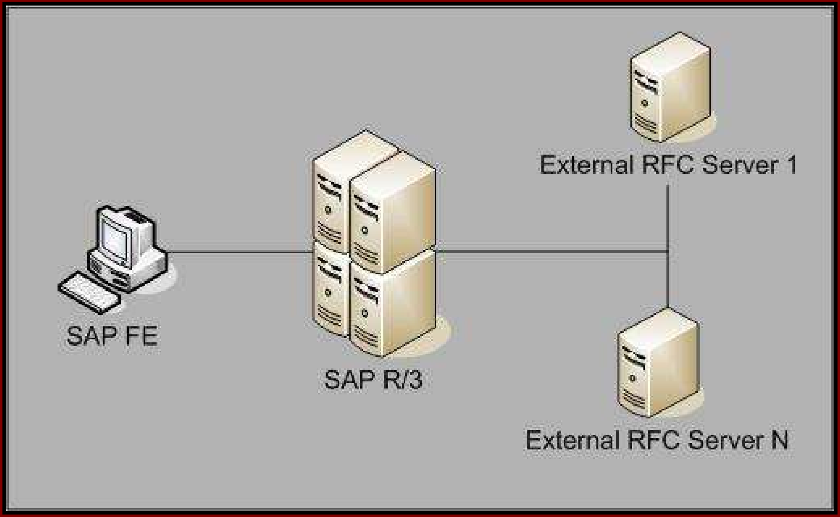
SAPXPG

- Executable shipped with SAP R/3 Application Server.
- Used for execution of external commands and programs.
- Installs the following functions:
  - SAPXPG_END_XPG
  - SAPXPG_START_XPG_LONG
  - SAPXPG_START_XPG

Advanced Attacks

Attacks Setup

- Scenario:



- We need some information about current deployment.
- How do we get it?
  - Network sniffing (RFC is clear-text!).
  - The Gateway Monitor.
  - Kidnapping an ABAP developer. (No step-by-step demonstration)

The Gateway Monitor

- The Gateway Server has a configuration parameter for controlling Gateway Monitor access.

```
gw/monitor = 0    Monitor is disabled.

gw/monitor = 1    Local access only.

gw/monitor = 2    Remote access enabled.
```

- Up to SAP Kernels 6.20, default value for this parameter is: 2
- Remote access to the Gateway Monitor would provide any information needed for the attacks.

Evil Twin

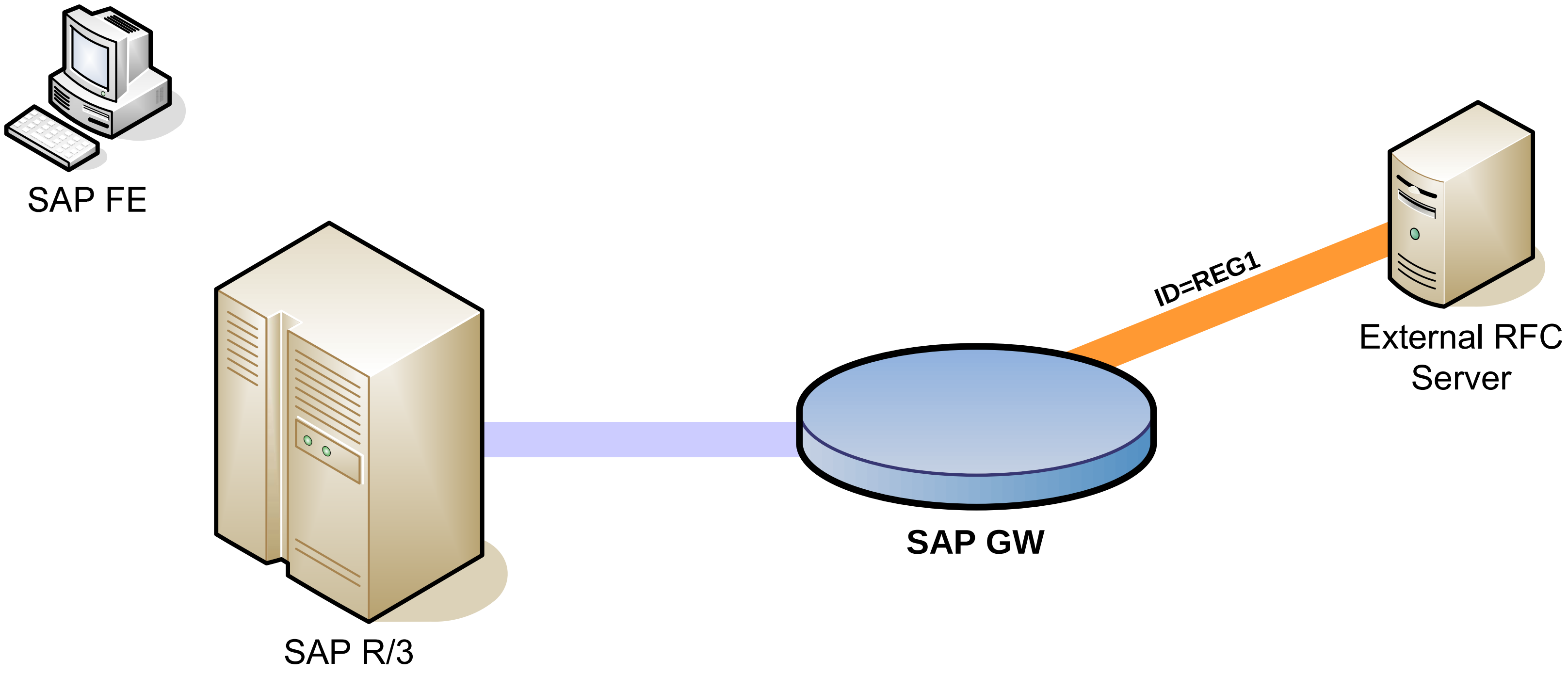
- Registration of External Servers can be done remotely.
- ACL for registration process is implemented through the *reginfo* file.
- By default, registration for everyone is allowed. (Registration Party!)

- External Servers can register several times with the same Program ID.
- ANY External Server can register with that ID!

- Attack:

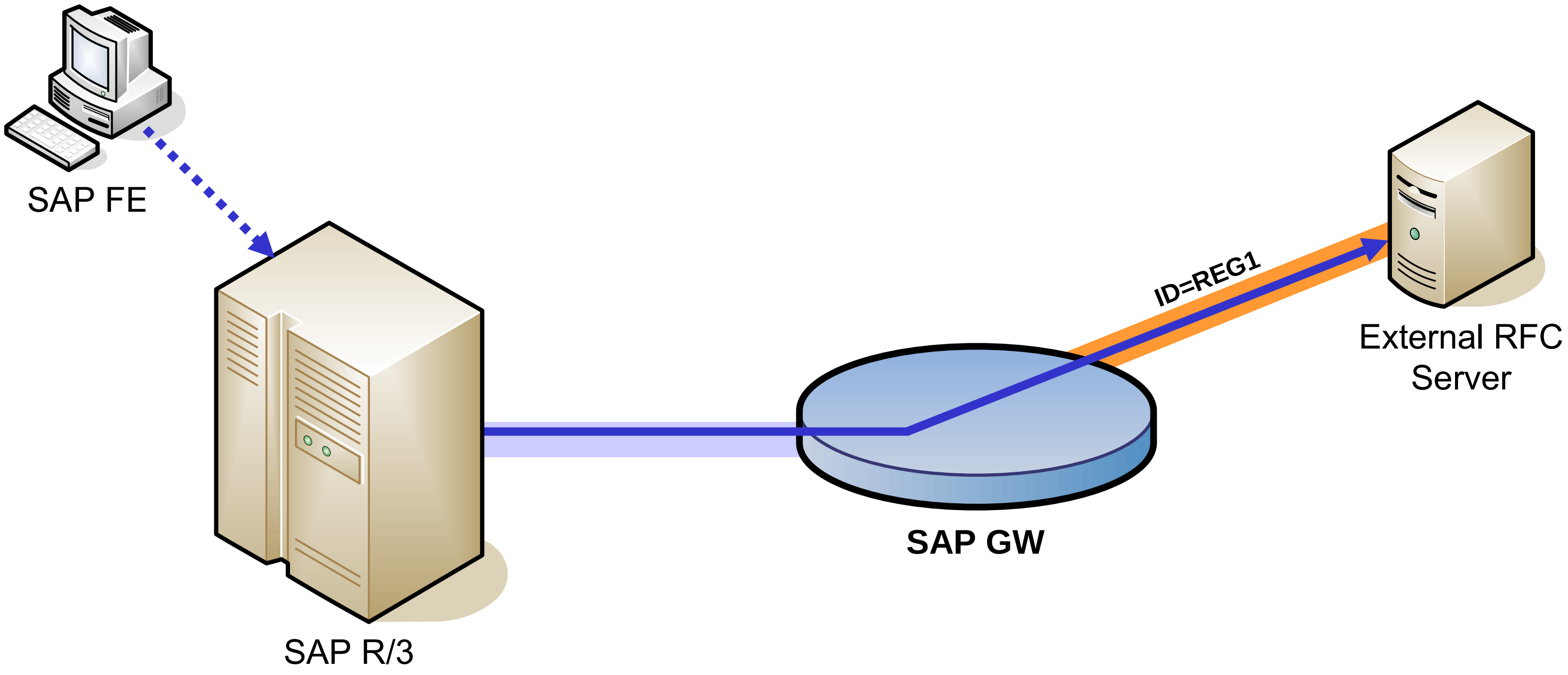
  1. Connect to licit Registered Server, ID=REG1 (blocking connections).
  2. Register External Server with ID=REG1.
  3. Drink some beer while watching calls arriving to our Evil Twin Server...

Evil Twin illustrated…



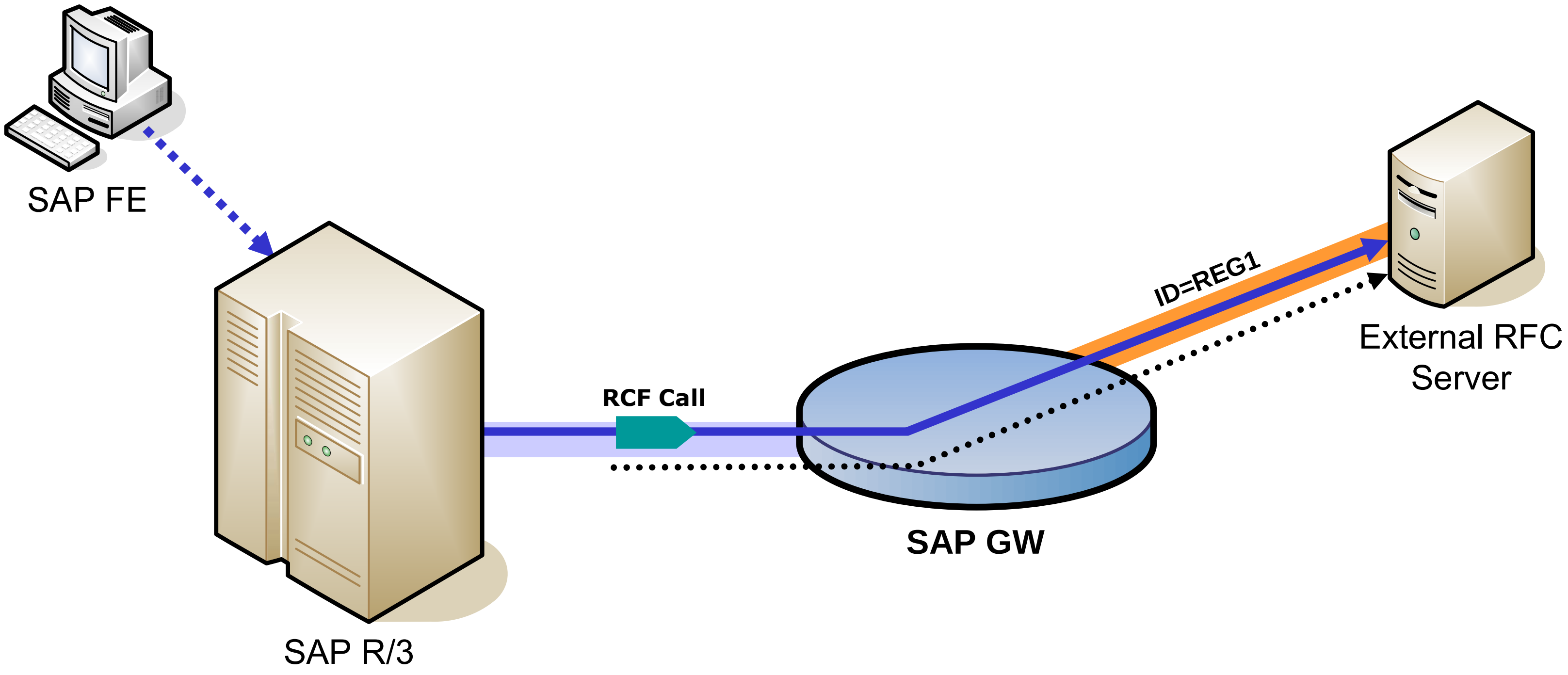
- Legimate External RFC Server registers at SAP R/3 Gateway.

Evil Twin illustrated…



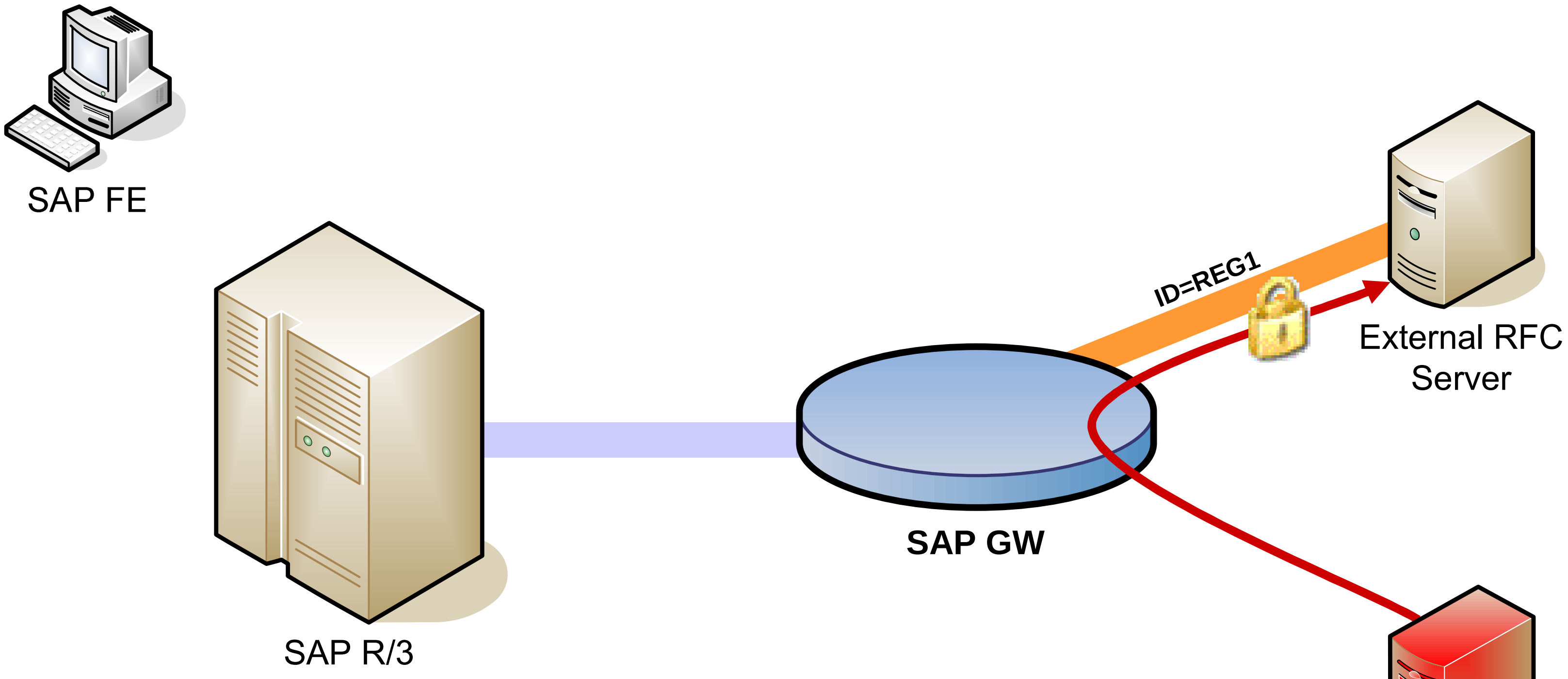
- Legimate External RFC Server registers at SAP R/3 Gateway.
- Innocent lamb connection establishment...

Evil Twin illustrated…



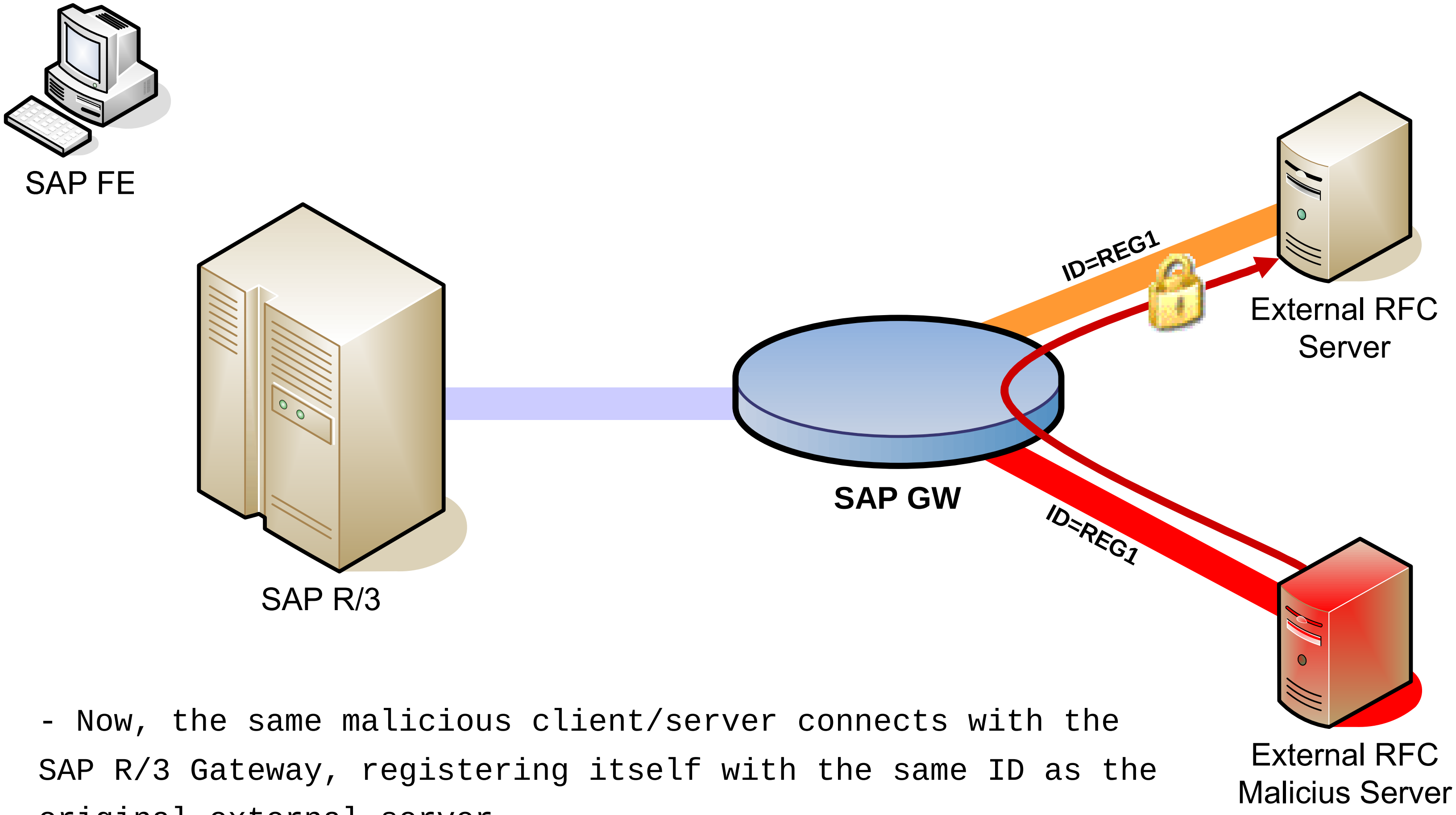
- Legimate External RFC Server registers at SAP R/3 Gateway.
- Innocent lamb connection establishment...
- Client performs RFC call and Server answers politely.

Evil Twin illustrated…



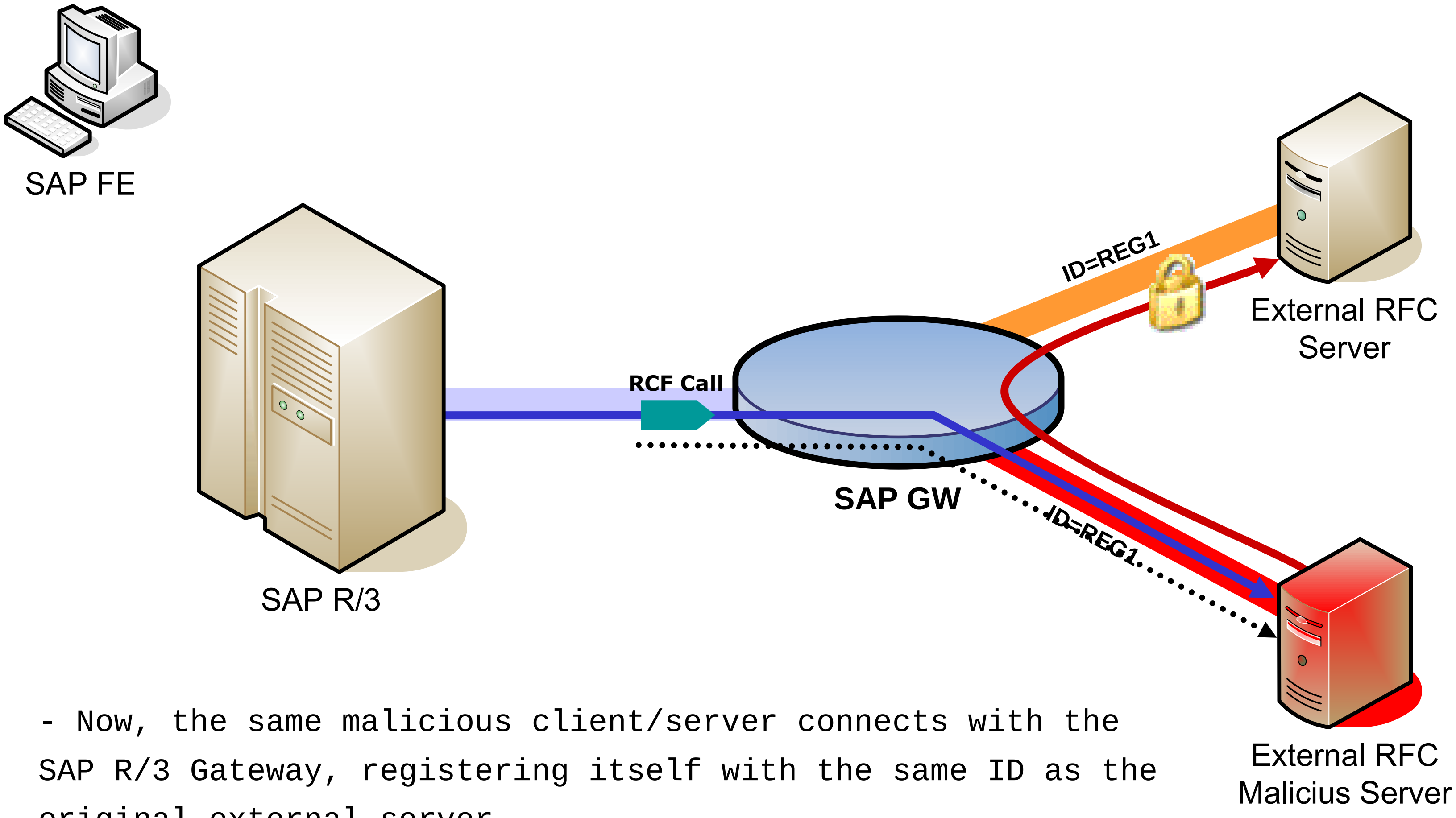
- An external RFC malicious client/server appears in scene... (don’t be afraid, it’s controlled)
- The attacker connects with the original RFC server, preventing him from serving requests from other clients.

Evil Twin illustrated…



- Now, the same malicious client/server connects with the SAP R/3 Gateway, registering itself with the same ID as the original external server

Evil Twin illustrated…



- Now, the same malicious client/server connects with the SAP R/3 Gateway, registering itself with the same ID as the original external server

- All future connections to the REG1 server will be attended by the evil one.

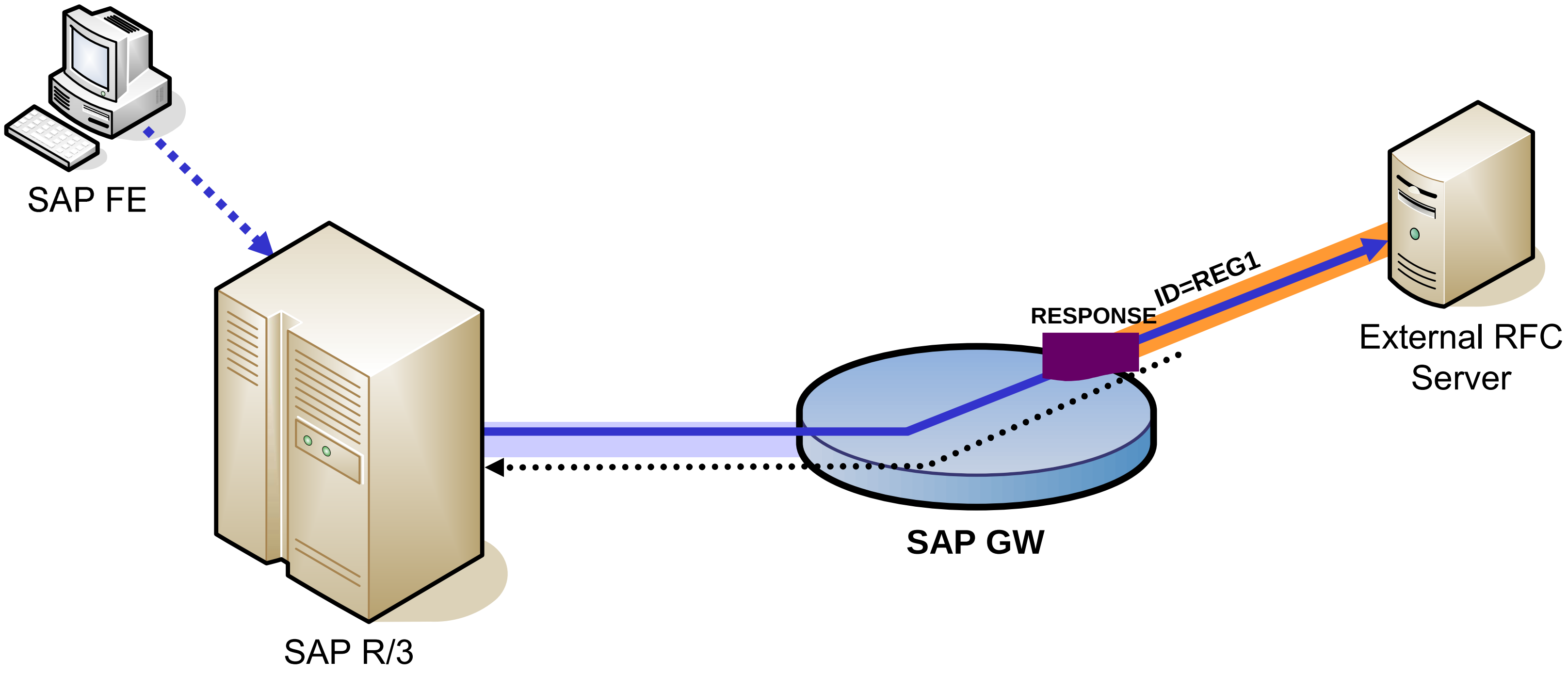
A Wiser (and Stealth) Evil Twin: MITM Attacks

- Proof of Concept.
- Attack:

I. Connect to licit Registered Server, ID=REG1 (blocking connections).

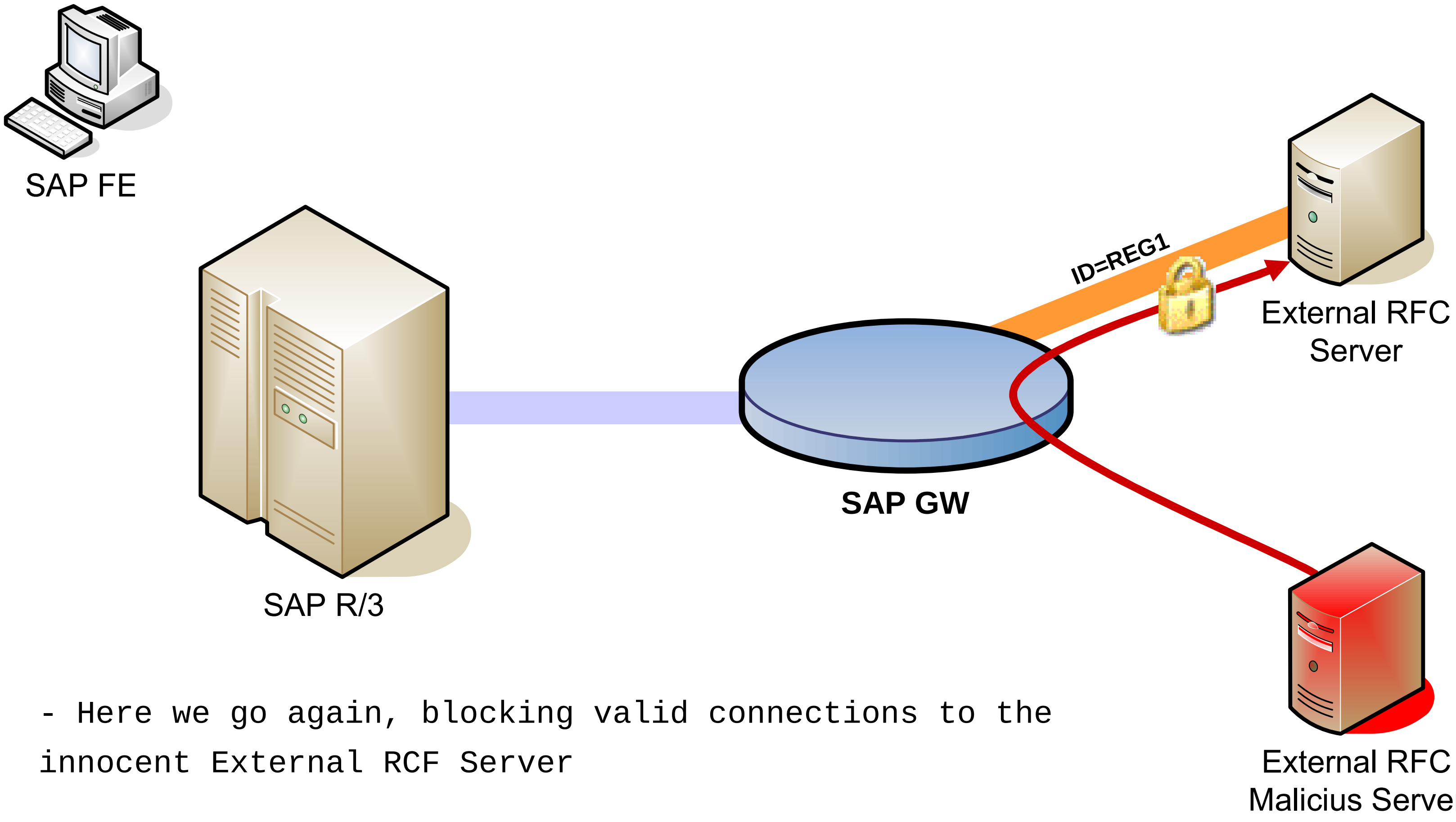
2. Register External Server with ID=REG1.
3. Receive RFC call.
4. Log / Modify Parameters values.
5. Use established connection with licit Registered Server to forward the (possible modified) RFC call.
6. Get results and send them to the original client.
7. Disconnect from the licit Registered Server.
8. Back to Step I.

A Wiser (and Stealth) Evil Twin: MITM Attacks



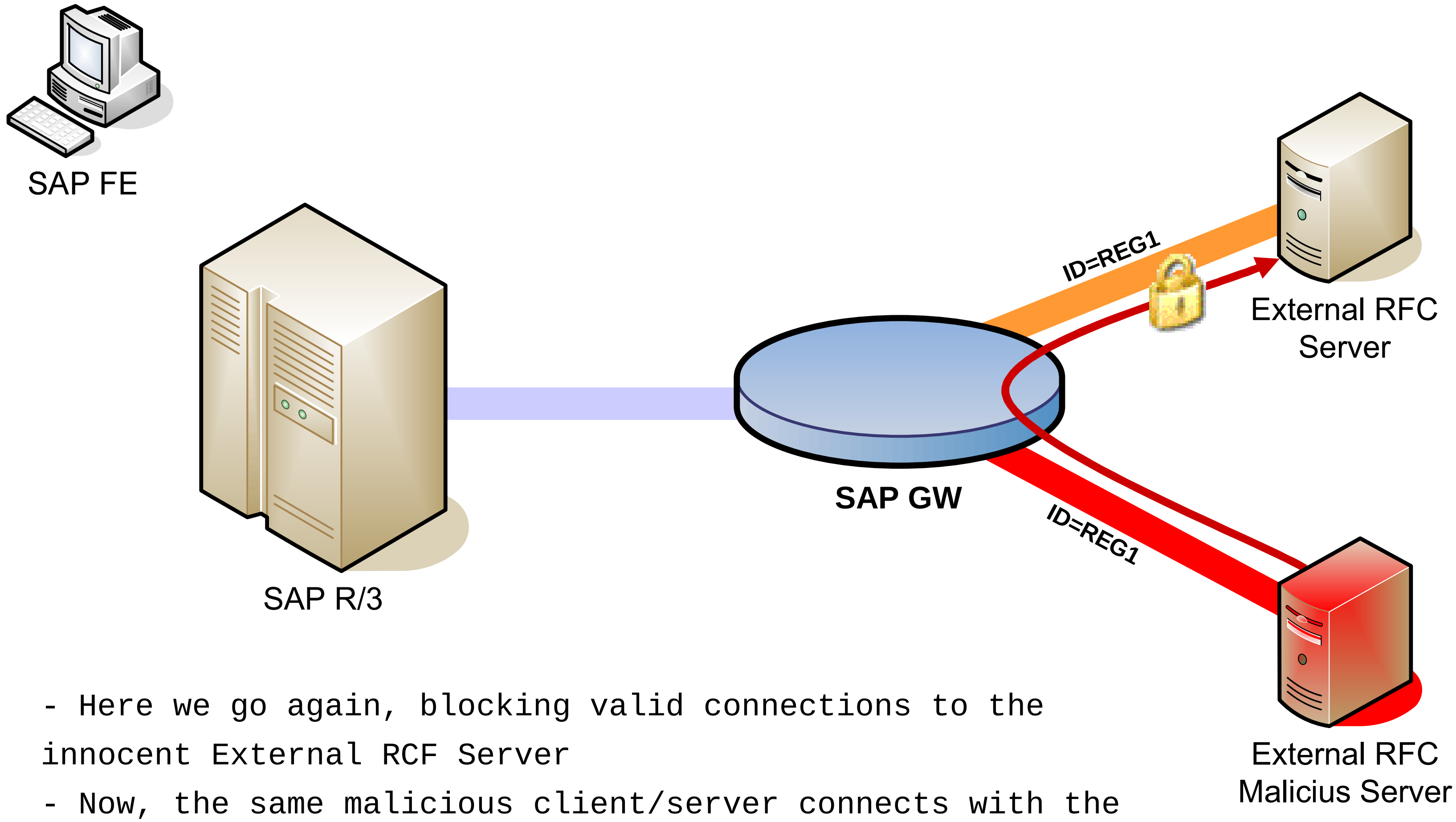
- So we have the same scenario, legitimate client and External RFC Server, the SAP R/3 Server and the SAP Gateway

A Wiser (and Stealth) Evil Twin: MITM Attacks



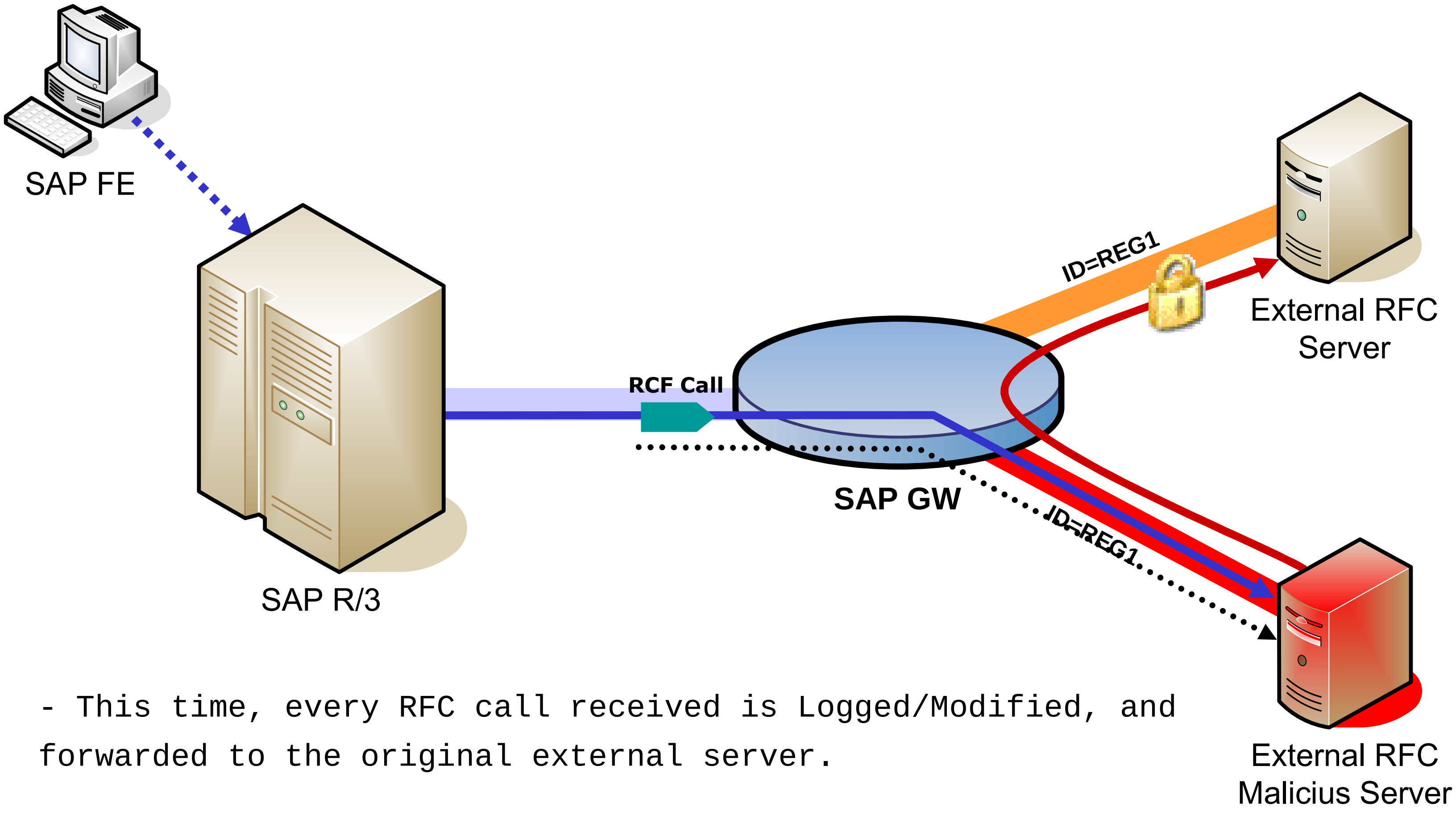
- Here we go again, blocking valid connections to the innocent External RCF Server

A Wiser (and Stealth) Evil Twin: MITM Attacks



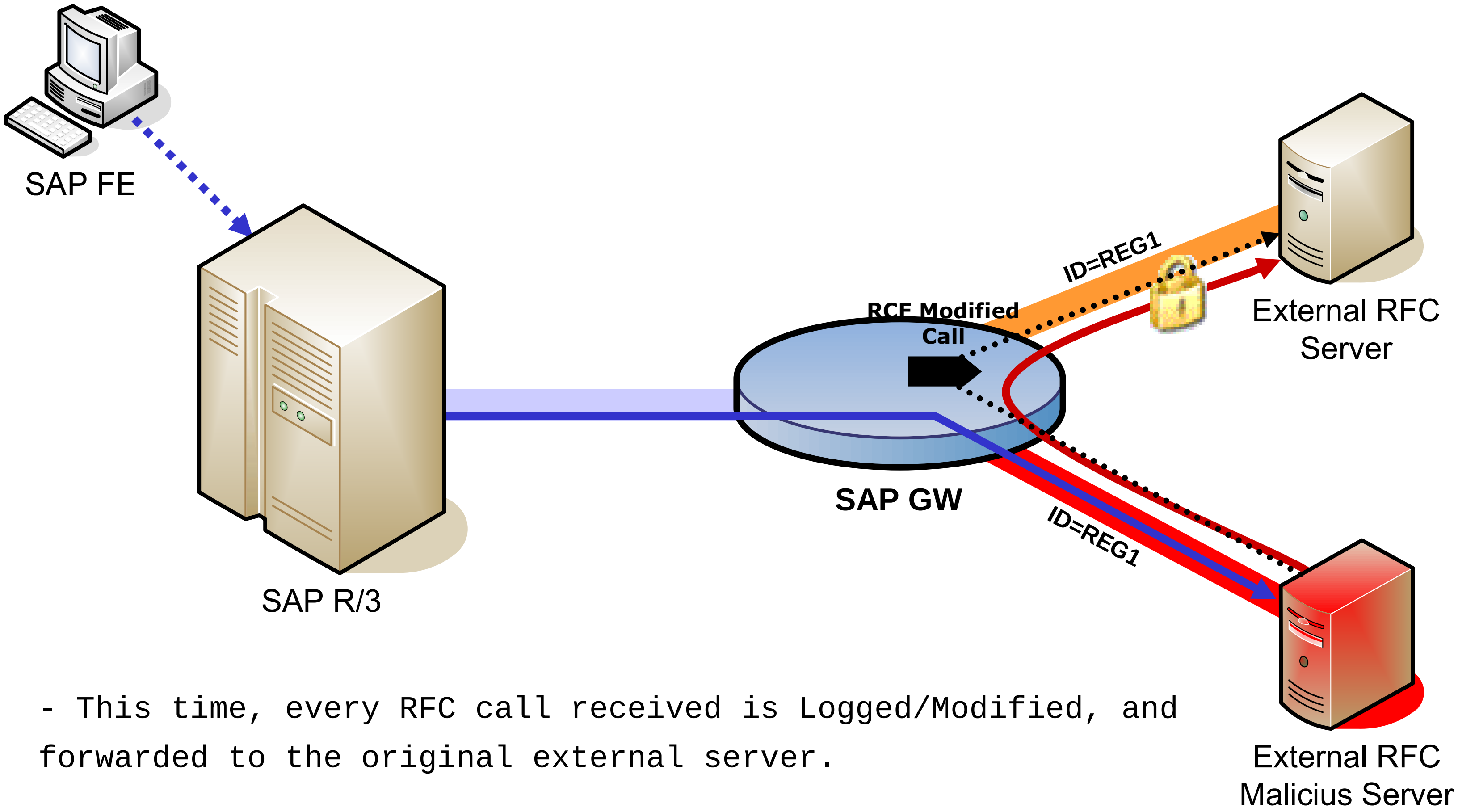
- Here we go again, blocking valid connections to the innocent External RCF Server
- Now, the same malicious client/server connects with the SAP R/3 Gateway, and register itself with the same ID as the original external server.

A Wiser (and Stealth) Evil Twin: MITM Attacks



- This time, every RFC call received is Logged/Modified, and forwarded to the original external server.

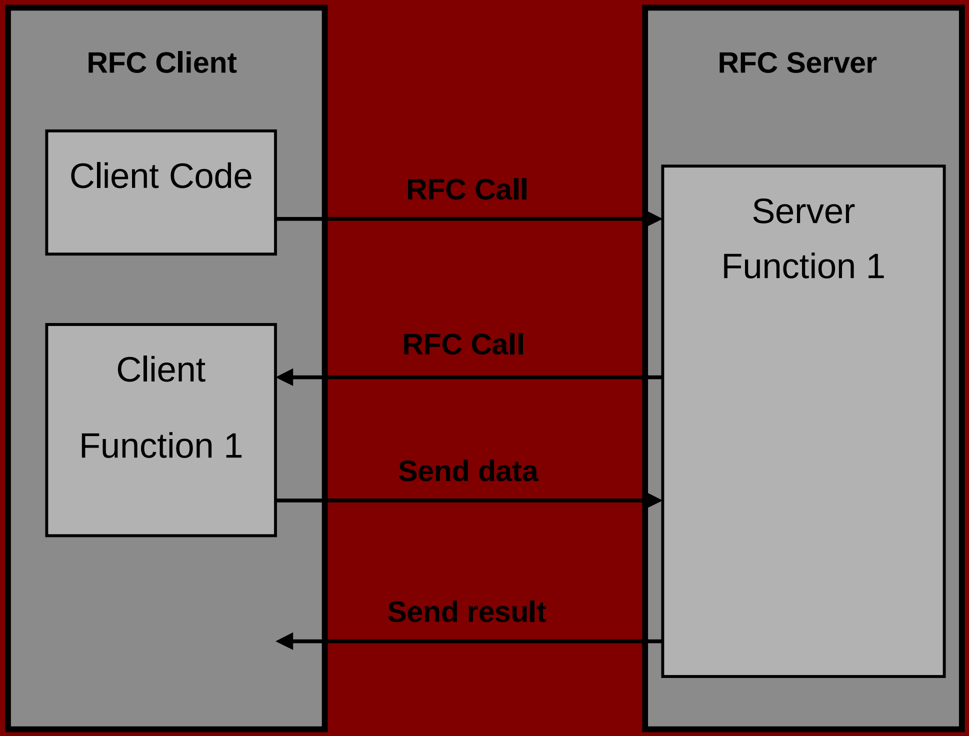
A Wiser (and Stealth) Evil Twin: MITM Attacks



- This time, every RFC call received is Logged/Modified, and forwarded to the original external server.

Attacking the R/3 with a Registered Server

- RFC Interface allows client / servers to perform "callbacks".

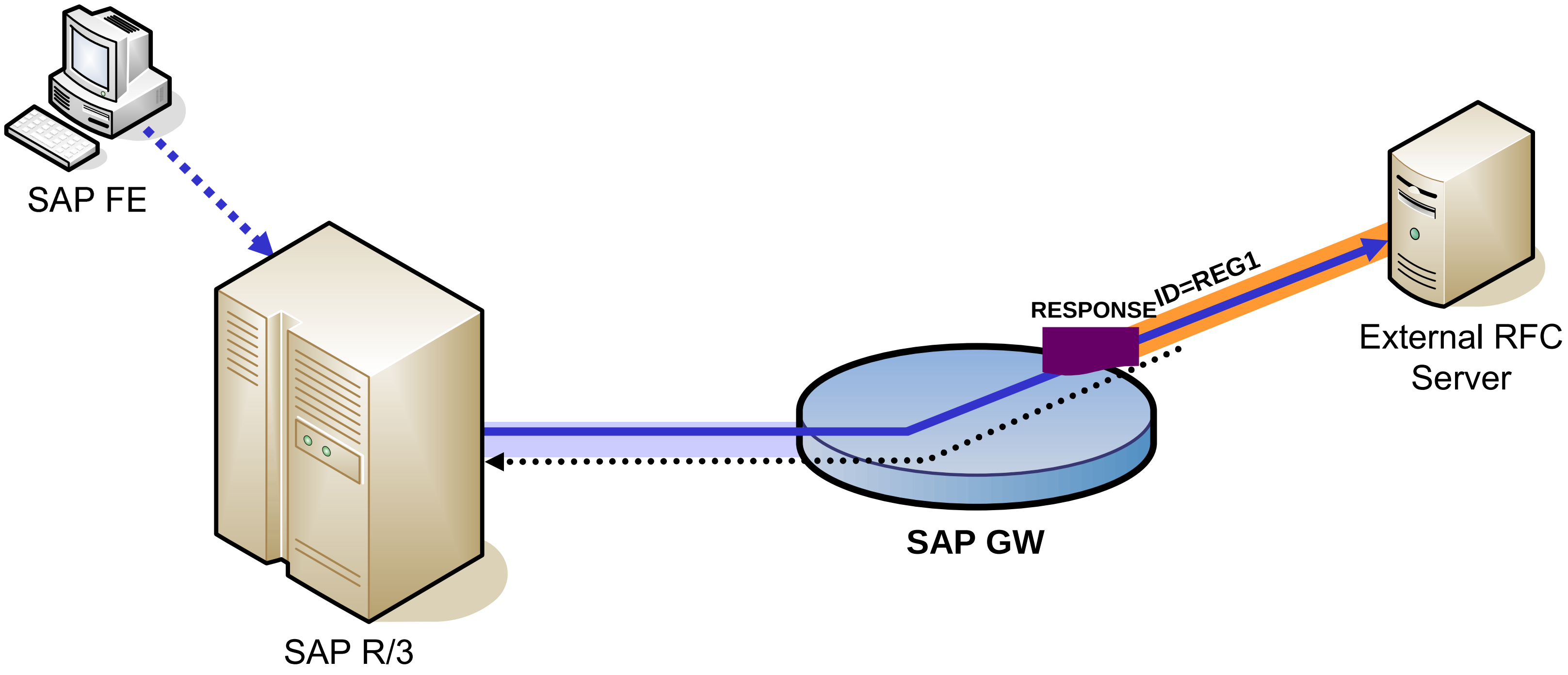


Attacking the R/3 with a Registered Server (cont.)

- We can perform "callbacks" to R/3 systems.
- The RFC Call is executed under the context of the original R/3 call.
- Impact depends on authorizations of the R/3 user (SAP_ALL?).
- Attack:

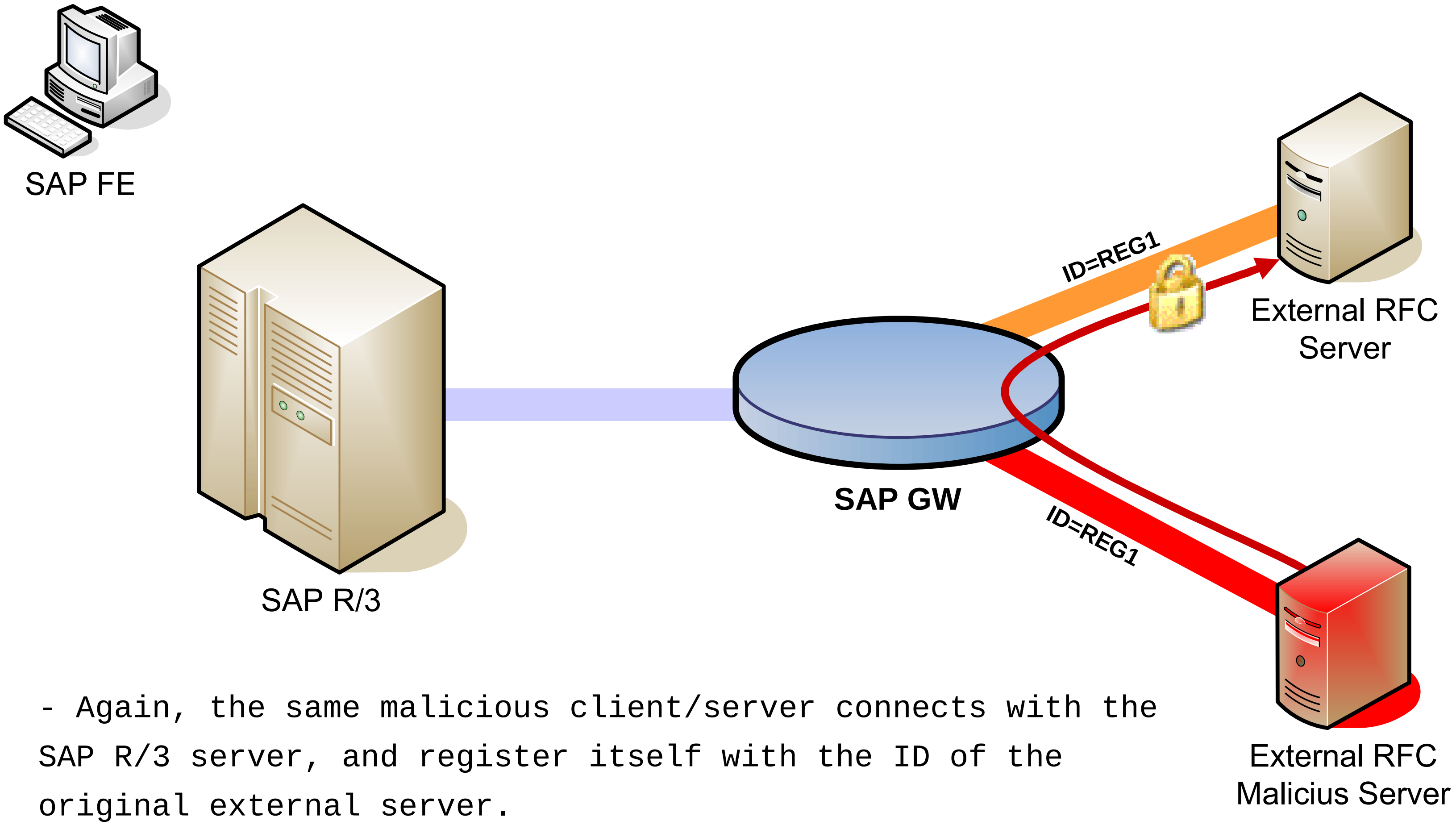
1. Connect to licit Registered Server, ID=REGI (blocking connections).
2. Start an Evil Twin.
3. Receive RFC call.
4. Perform RFC callback.
5. If user has SAP_ALL...Bingo!

Attacking the R/3 with a Registered Server (cont.)



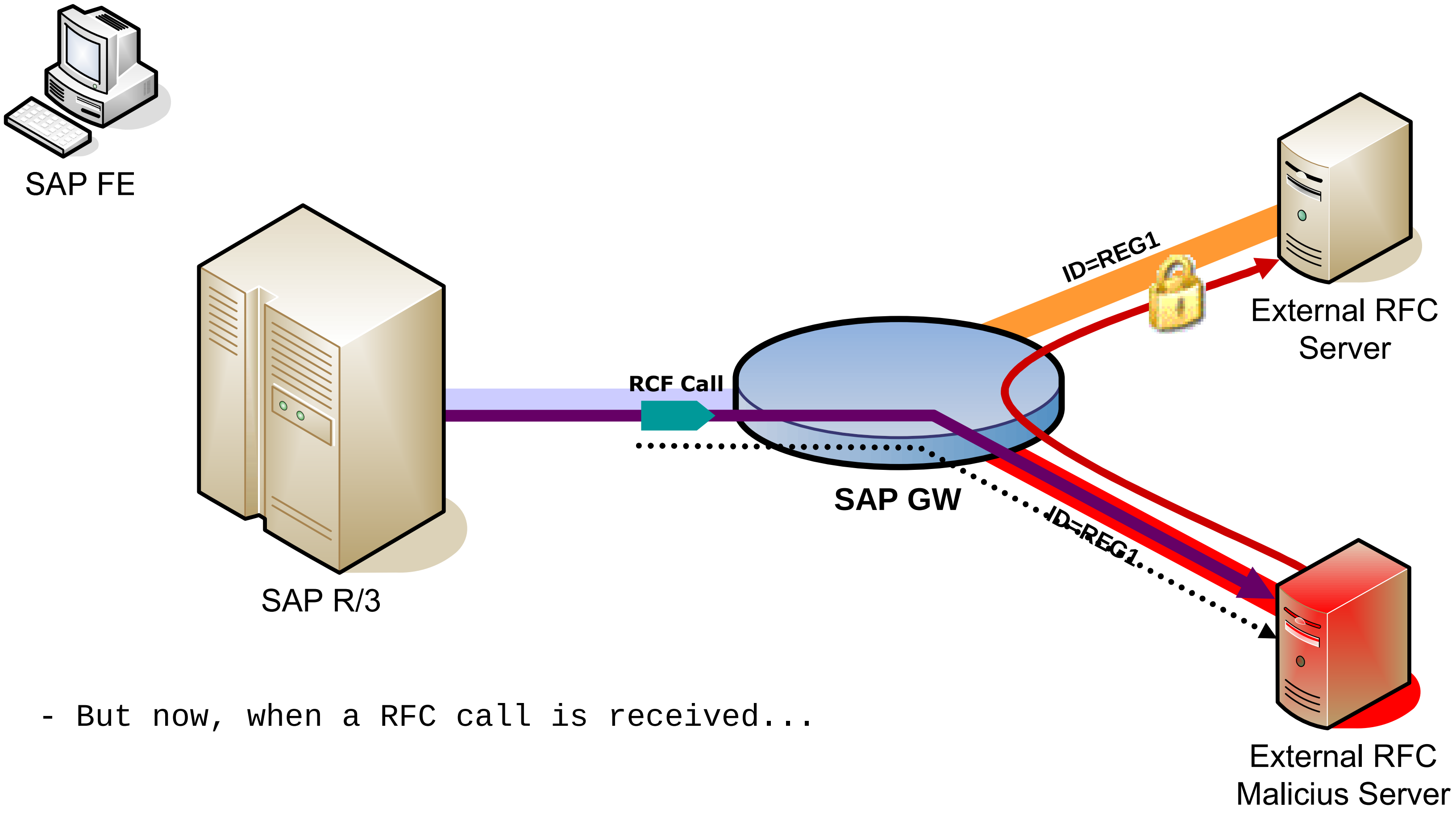
- Yes, again the same scenario: the valid client, the valid External RFC Server, the SAP R/3 Server and the SAP Gateway

Attacking the R/3 with a Registered Server (cont.)



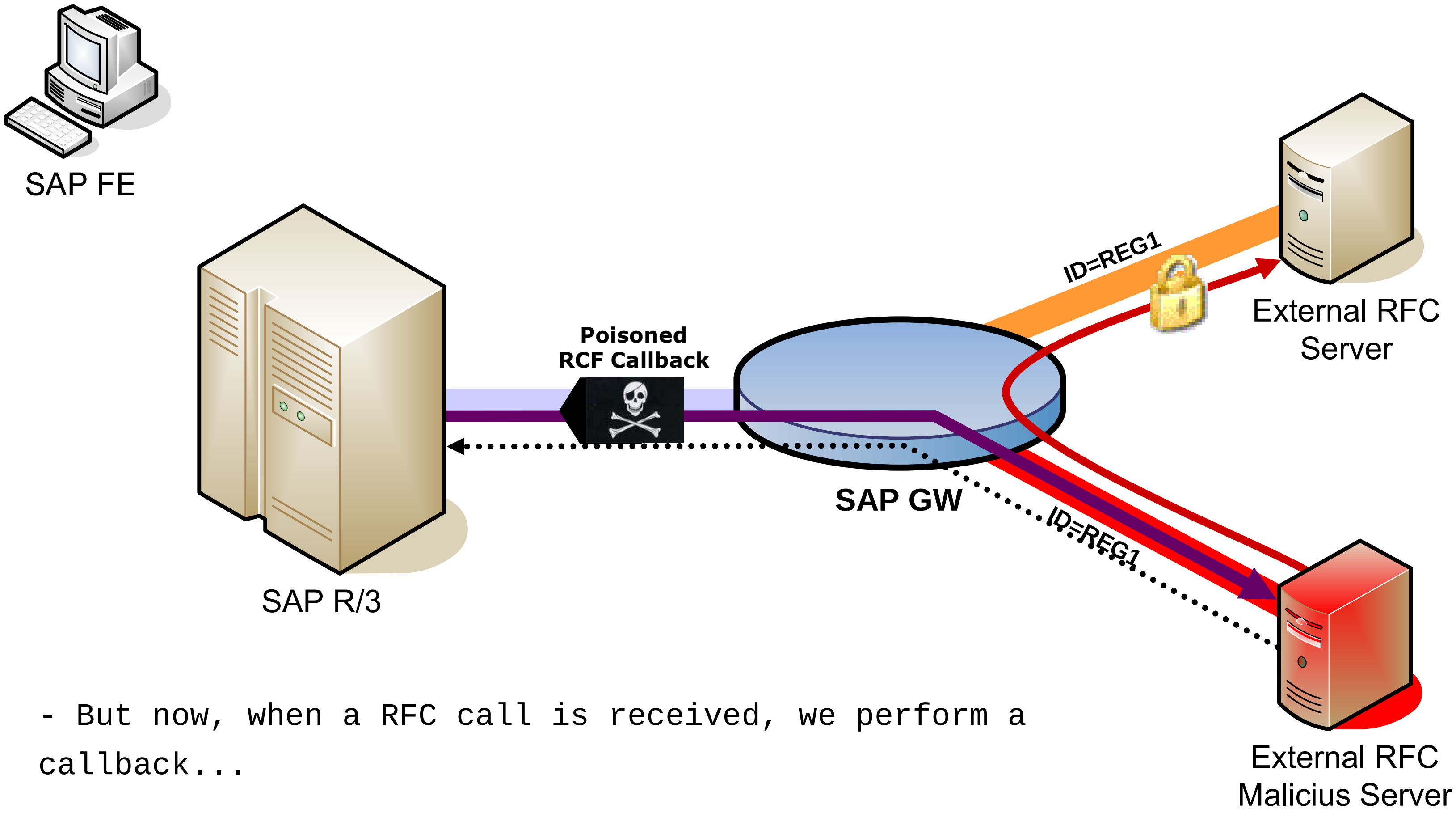
- Again, the same malicious client/server connects with the SAP R/3 server, and register itself with the ID of the original external server.

Attacking the R/3 with a Registered Server (cont.)



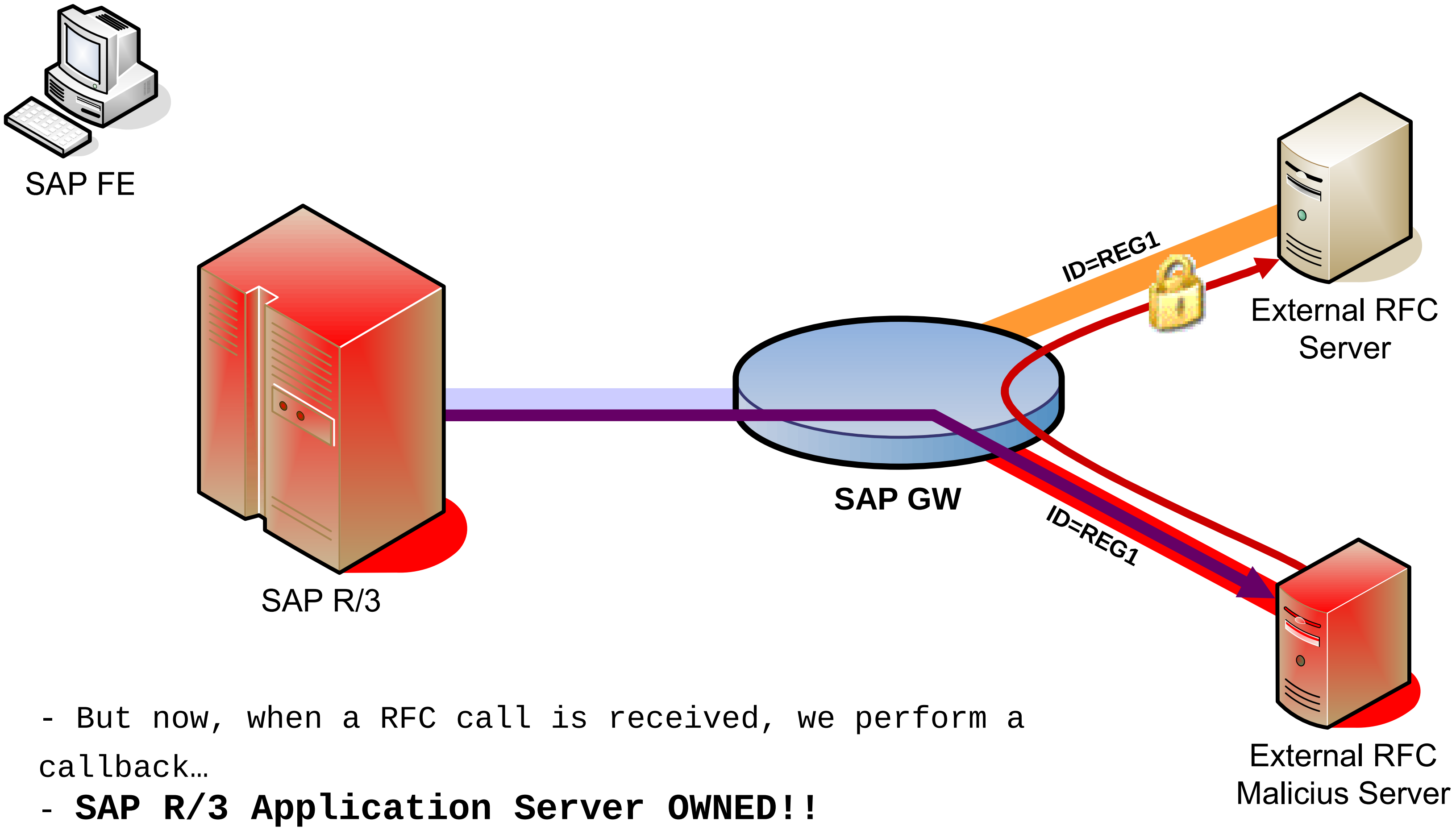
- But now, when a RFC call is received...

Attacking the R/3 with a Registered Server (cont.)



- But now, when a RFC call is received, we perform a callback...

Attacking the R/3 with a Registered Server (cont.)



- But now, when a RFC call is received, we perform a callback…
- **SAP R/3 Application Server OWNED!!**

Tool Release:

sapyto

sapyto

- First public framework for performing SAP Penetration Tests.
- Core dependencies: SAP RFC Library and saprfc module.
- Plugin based.
- Audit & Attack Plugins.
- Shipped with plugins for exploiting RFC vulnerabilities, auditing SAP R/3 configuration, launching described attacks, etc..
- Developed in Python and C.

Available Plugins in Beta Version

- Audit:
  - RFC Ping.
  - Registration of External Servers.
  - Detection of RFCEXEC.
  - Detection of SAPXPG.
  - Get system information.
  - Get server documentation.

Available Plugins in Beta Version (cont.)

- Attack:
  - RFC_START_PROGRAM Directory Trasversal.
  - Run commands through RFCEXEC.
  - Run commands through SAPXPG.
  - StickShell.
  - Evil Twin Attack.
  - Get remote RFCShell.

- Tools:
  - RFC Password Obfuscator / De-obfuscator.

sapyto Demonstration

Conclusions & Comments

- The RFC Interface is a wide door into SAP Systems. It has to be locked!
- SAP has responded quickly and provided solutions with SAP notes 1003908, 1003910, 1004084, and 1005397.
- SAP Administrators must apply patches.
- SNC prevents credential and information sniffing. It is included in SAP systems and must be activated.
- Network must be properly segmented.
- Advanced attacks described can be avoided with proper configuration + patches.

Coming soon…

- Attacking SAP clients.
- SAP Backdoors.
- ABAP Worms.
- Exploiting Trusted Systems.
- RFC Fuzzer.
- …

Stay tunned!

Questions?

Thank you!

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