Automatic Generation of Data-Oriented Exploits

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    - heap spray / JIT spray

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  - Code injection
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    - ret2libc, ROP
    - control-flow bending
- Defenses
  - Data Execution Prevention
  - Control Flow Integrity

- Stat-of-the-art exploits from memory errors
  - Code injection (e.g., heap spray / JIT spray)
  - Code reuse (e.g., ret2libc, ROP)
- Defenses
  - DEP, CFI, ASLR
  - Block control flow hijacking in principle

CONTROL PLANE


DATA PLANE
Defenses
DEP, CFI, ASLR
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CONTROL PLANE

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......
// set normal user privilege
seteuid(pw->pw_uid);
// execute user’s command
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```
//0x1D4, 0x1E4 or 0x1F4 in JScript 9,
//0x188 or 0x184 in JScript 5.8,
safemode = *(DWORD *)(jsobj + 0x188);
if( safemode & 0xB == 0 ) {
        Turn_on_God_Mode();
}
```

IE *SafeMode* Bypass+

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  - Systematic search for data-oriented exploits
  - Works on binary directly

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- Data Flow Stitching
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  - Works on binary directly
- Results
  - Concrete exploits on real web/file servers
  - 19 exploits (16 new) from 8 vulnerabilities

Motivating Example

- SSL-enabled web server

```
int server() {
 char *userInput, *fileName;
 char *privKey, *result, output[BUFSIZE];
 char fullPath[BUFSIZE]="/path/to/root/";

 privKey=loadPrivKey("/path/to/privKey");
 GetConnection(privKey, ...);
 userInput = read_socket();
 if (checkInput(userInput)) {
  fileName = getFileName(userInput);
  strcat(fullPath,  fileName);
  result = retrieve(fullPath);
  sprintf(output, “%s:%s”, fileName, result);
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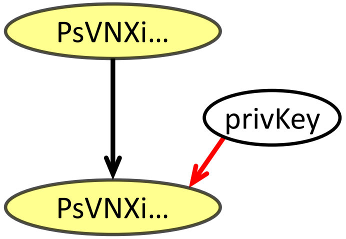

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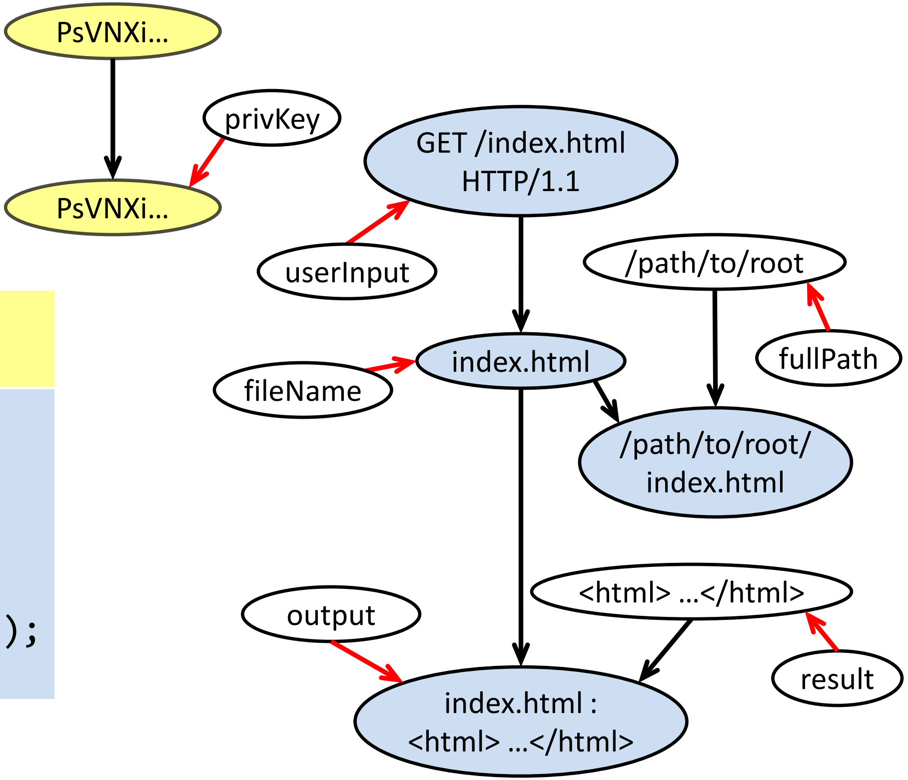

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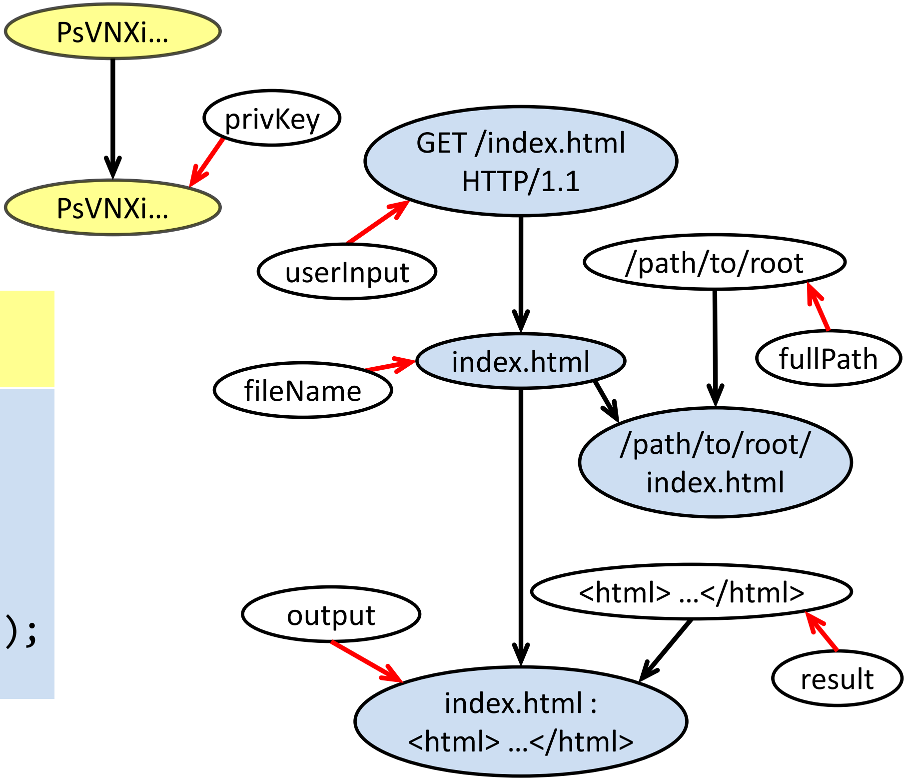

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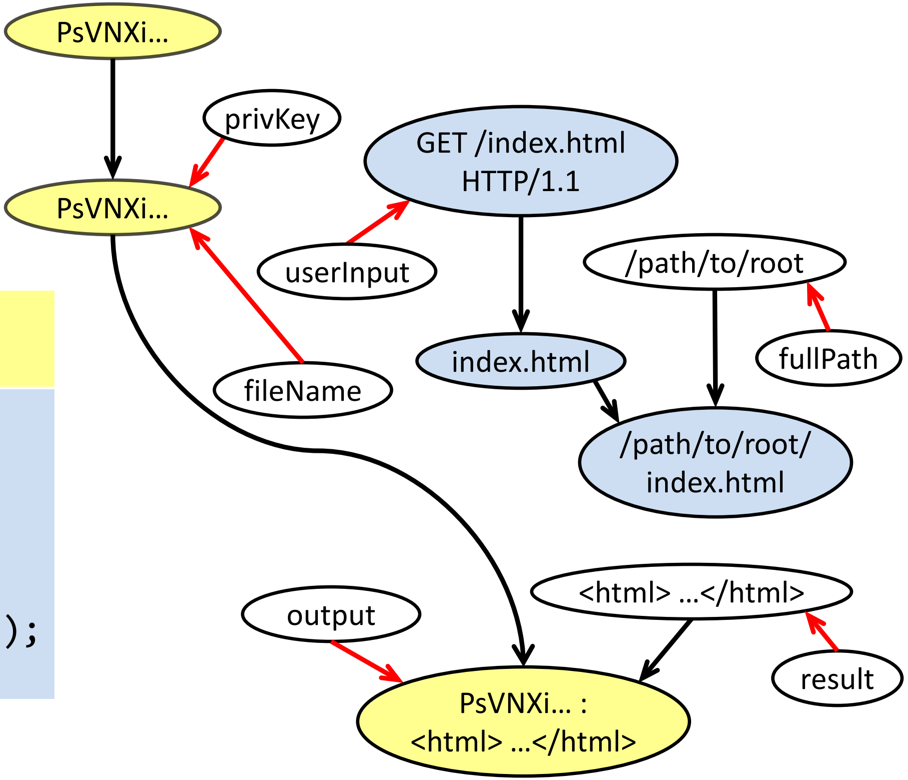
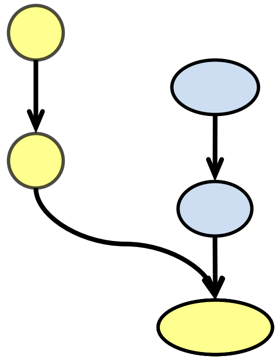


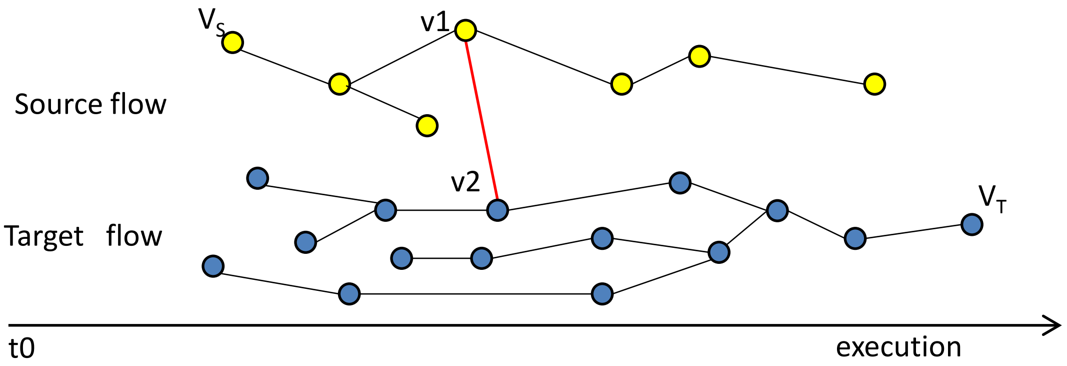
Data-Flow Stitching



- Manipulate data flows for exploits
- Enables systematic way to search for exploits
  - Input: binary & error-exhibiting input
  - Output: data-oriented exploits
- Goal:
  - Information Leakage (e.g., password, keys)
  - Privilege Escalation (e.g., setuid, access priv. files)
- Constraints:
  - Keep the control-flow same
  - Prevent abrupt termination
  - No knowledge of randomized values (CFI tags, ASLR addresses)

Challenges

- Time-consuming search
  - The search-space: Cartesian product |SrcFlow| ***X*** |TgtFlow|
  - Heavy analysis for each candidate



- Our solution:
  - Filter out candidates with memory error influence
  - Use an SMT solver to verify candidates

Single-Edge Stitch

- Corrupt data vertex

```
struct passwd {uid_t pw_uid; ... } pw;
...
int uid = getuid();
pw->pw_uid = uid;
printf(...); //format string error
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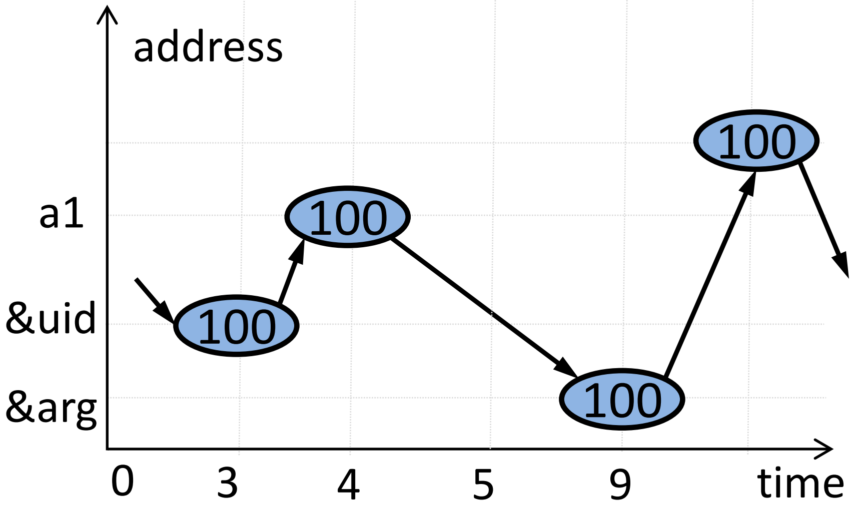
- 2D-DFG



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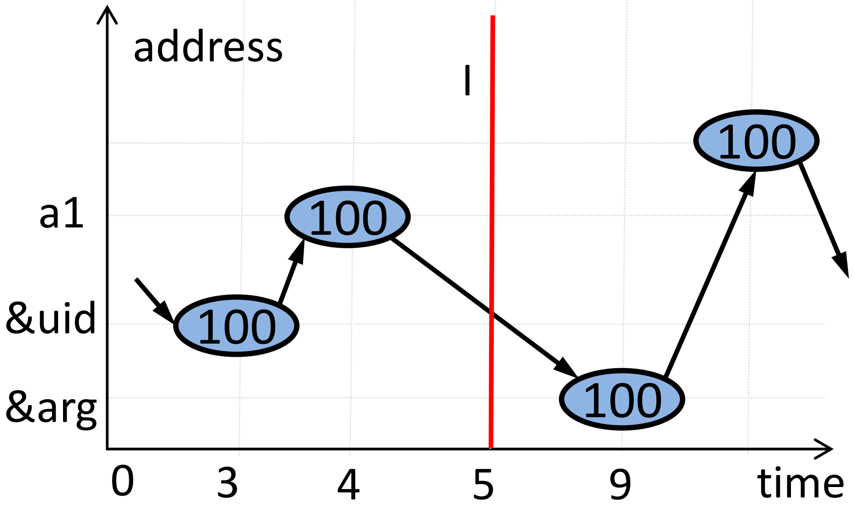

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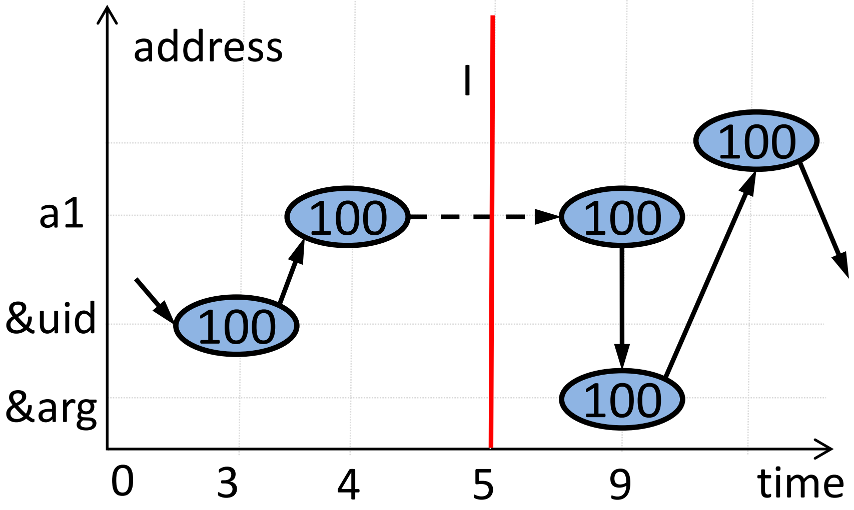

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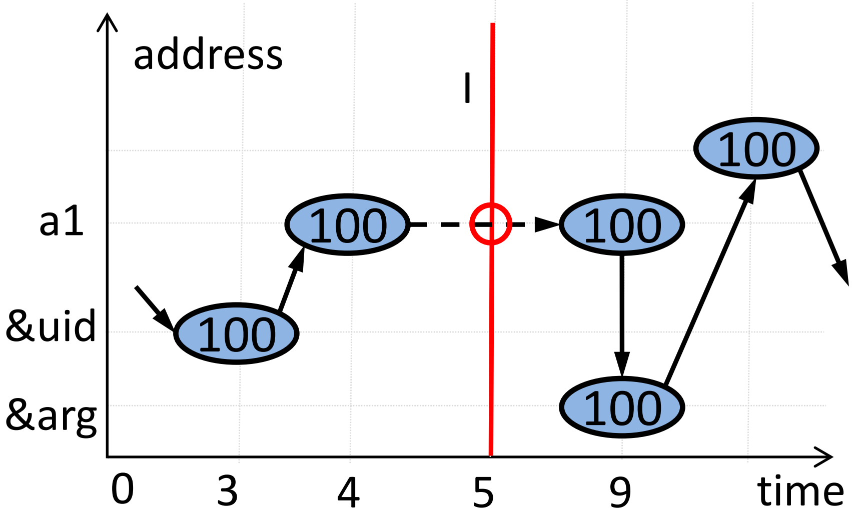

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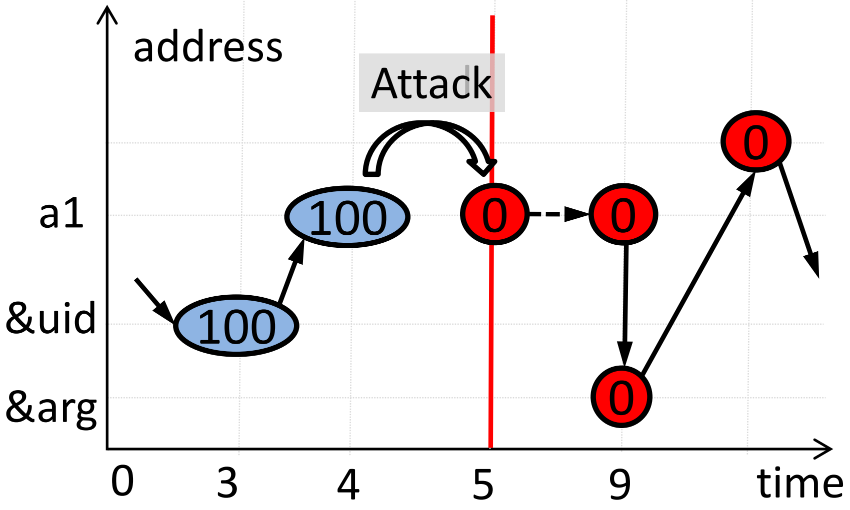

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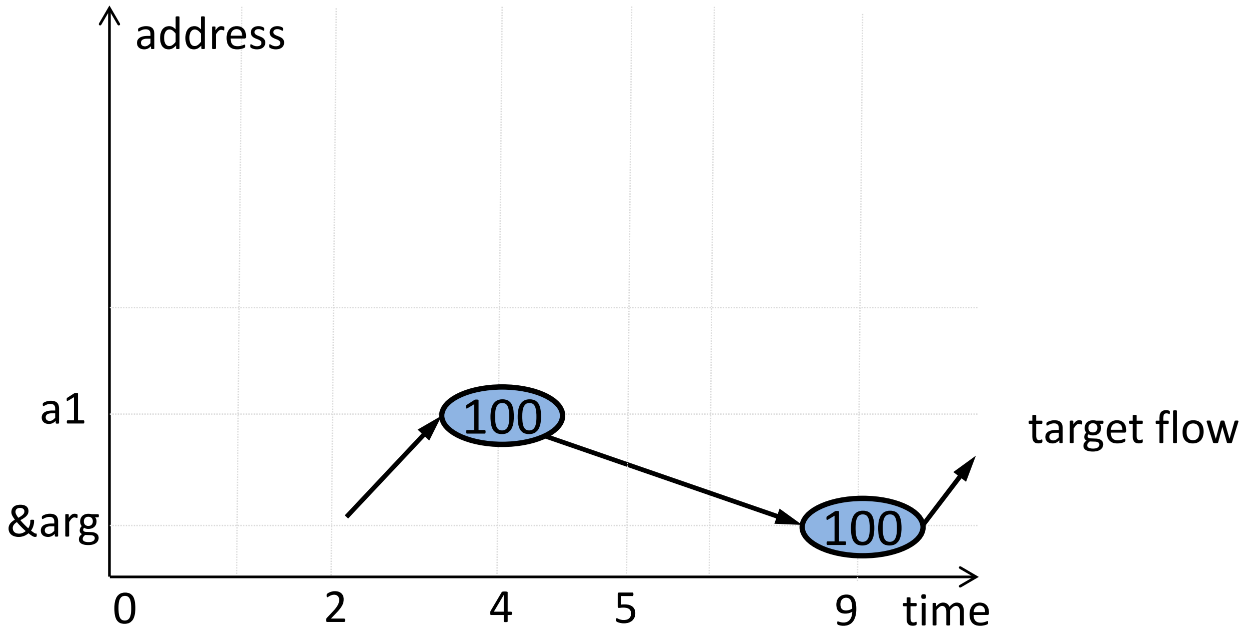
- Corrupt pointers to connect data flows
  - Pointers decide data movement direction



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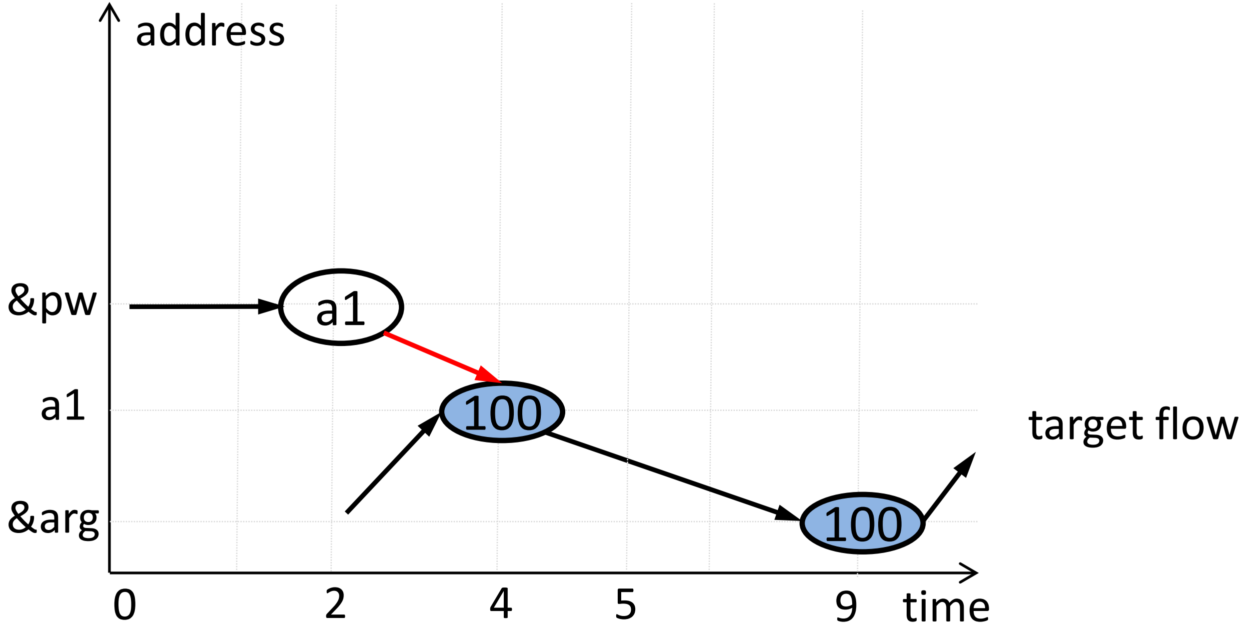

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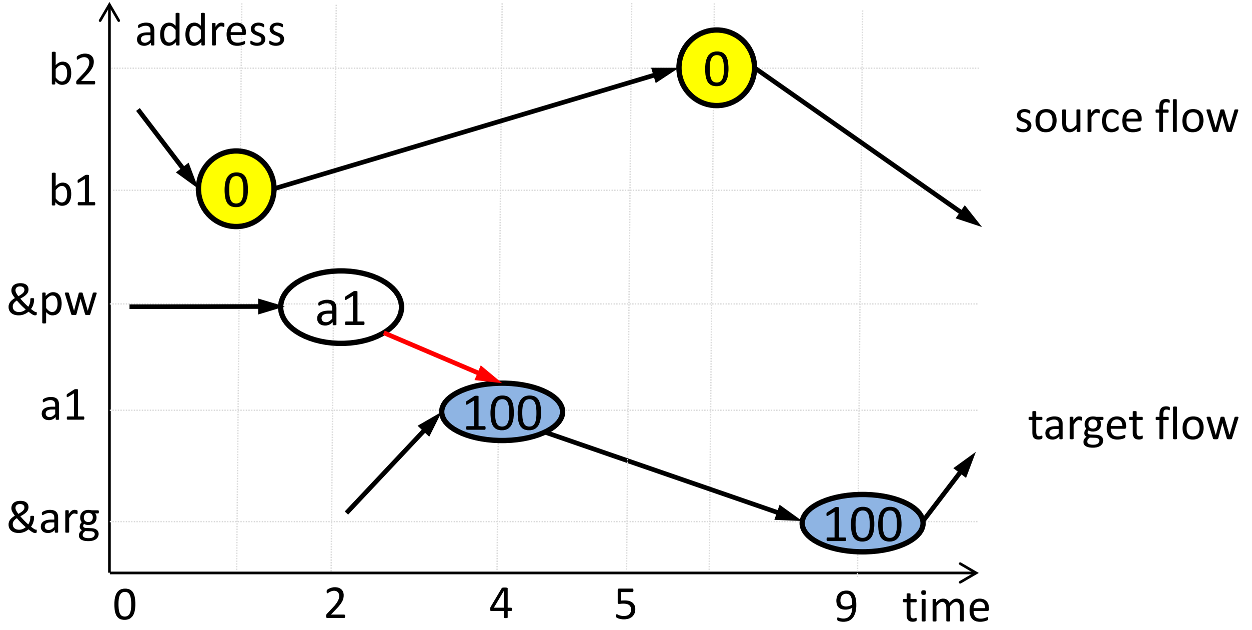

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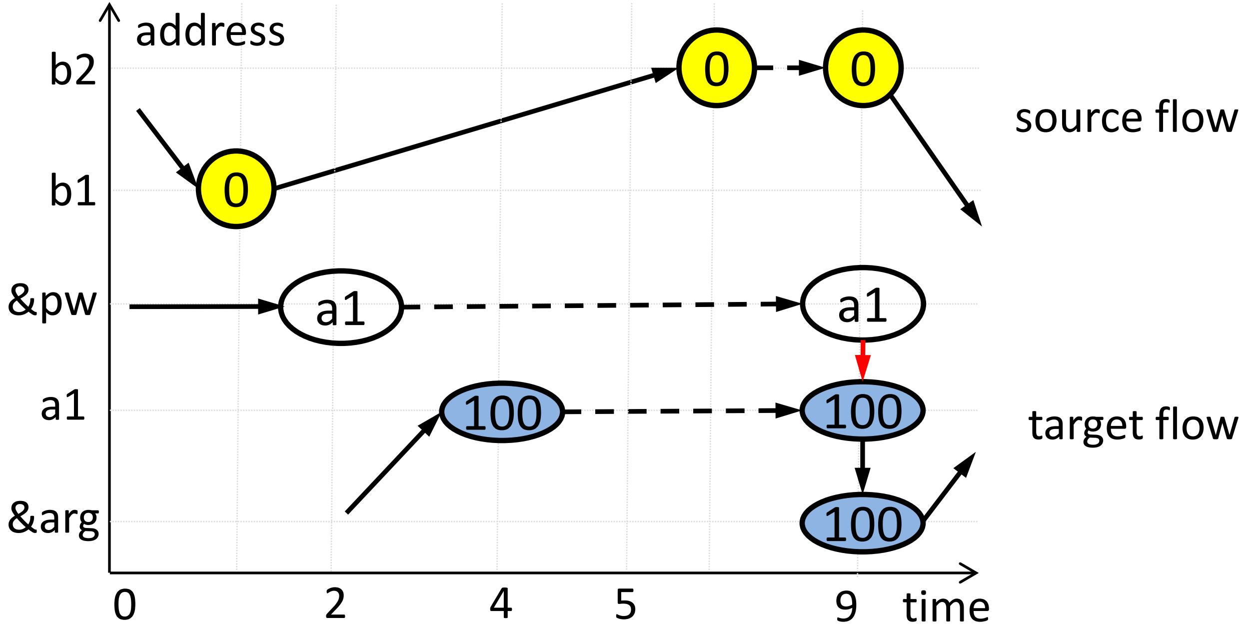

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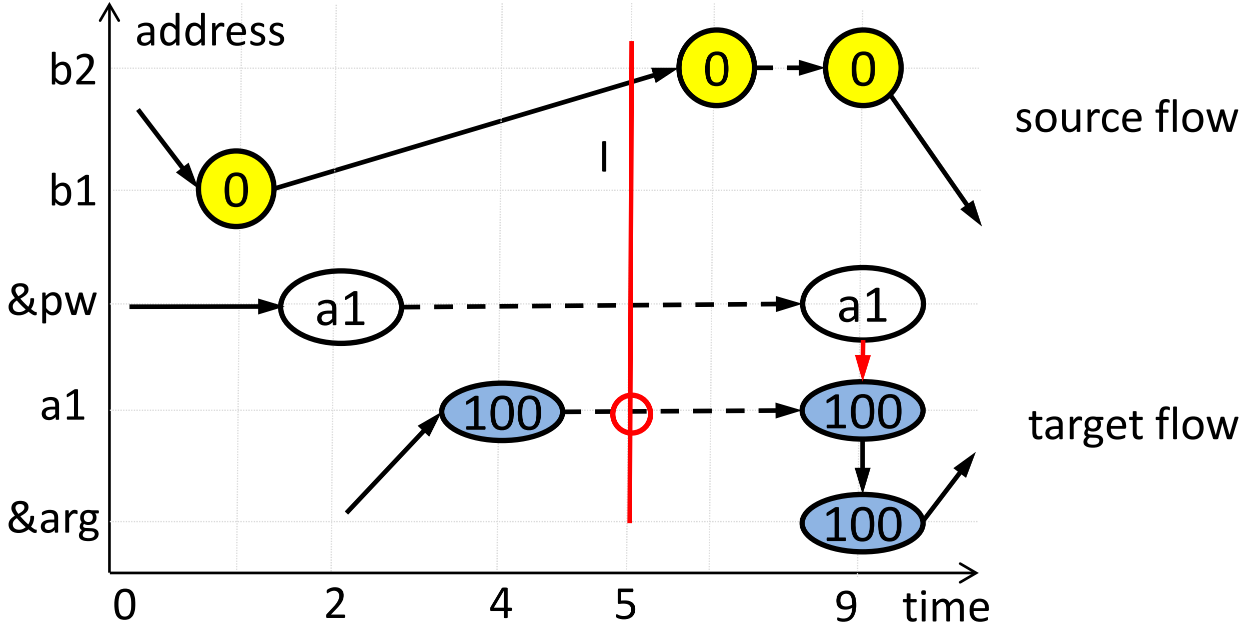

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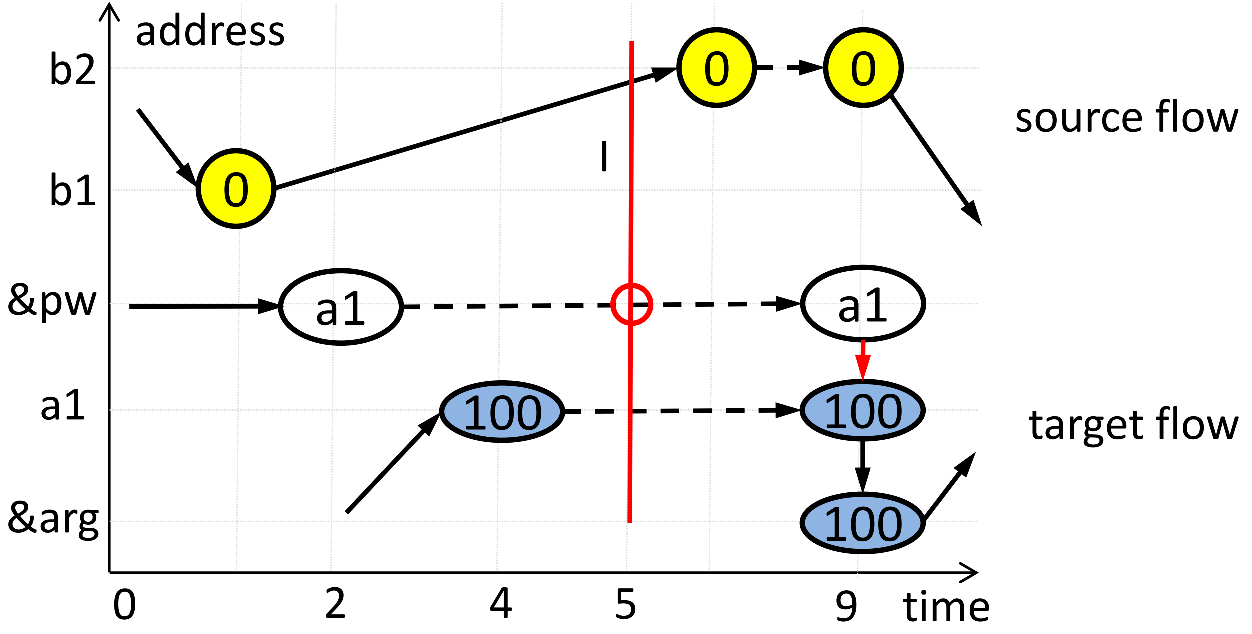

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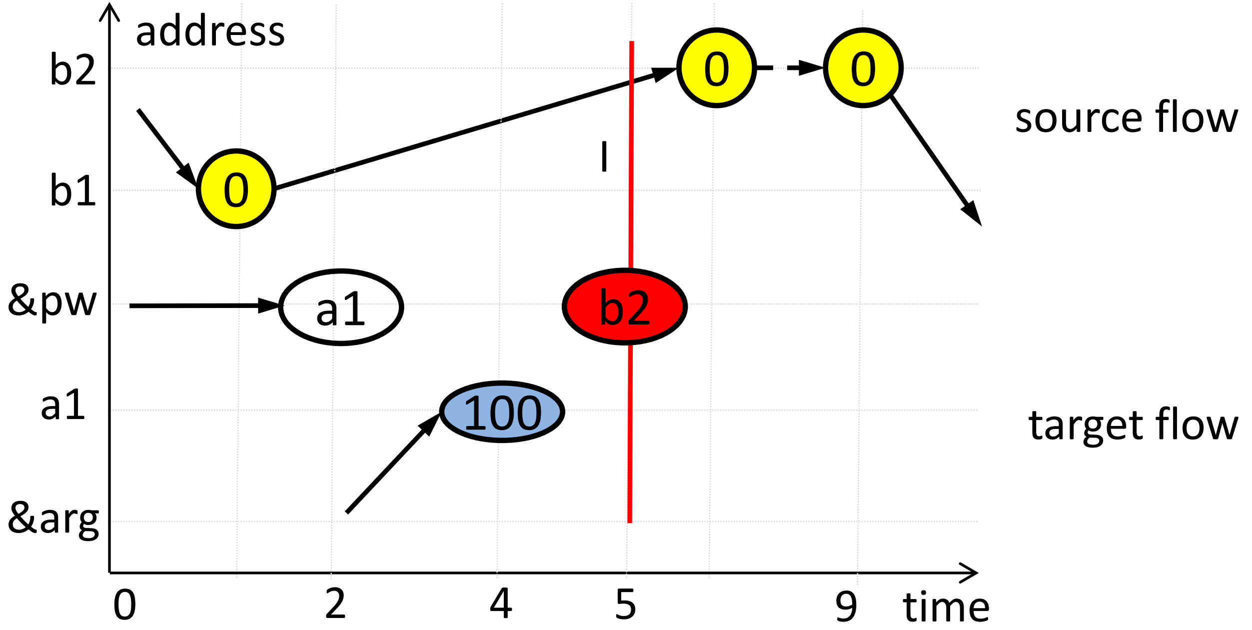

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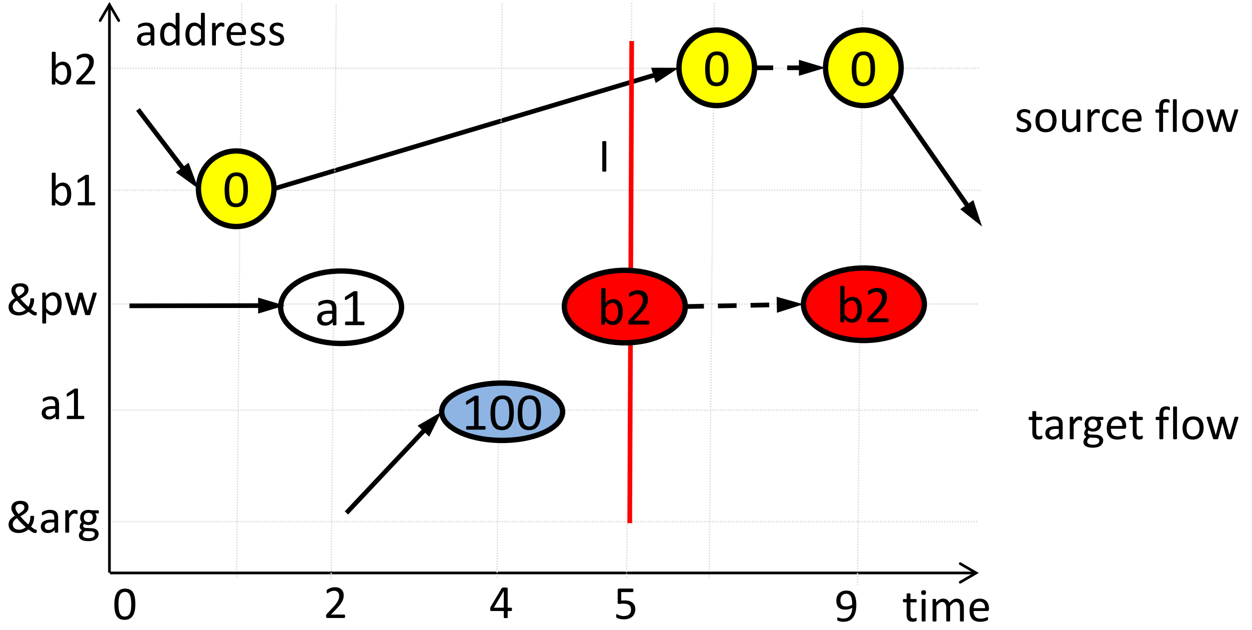

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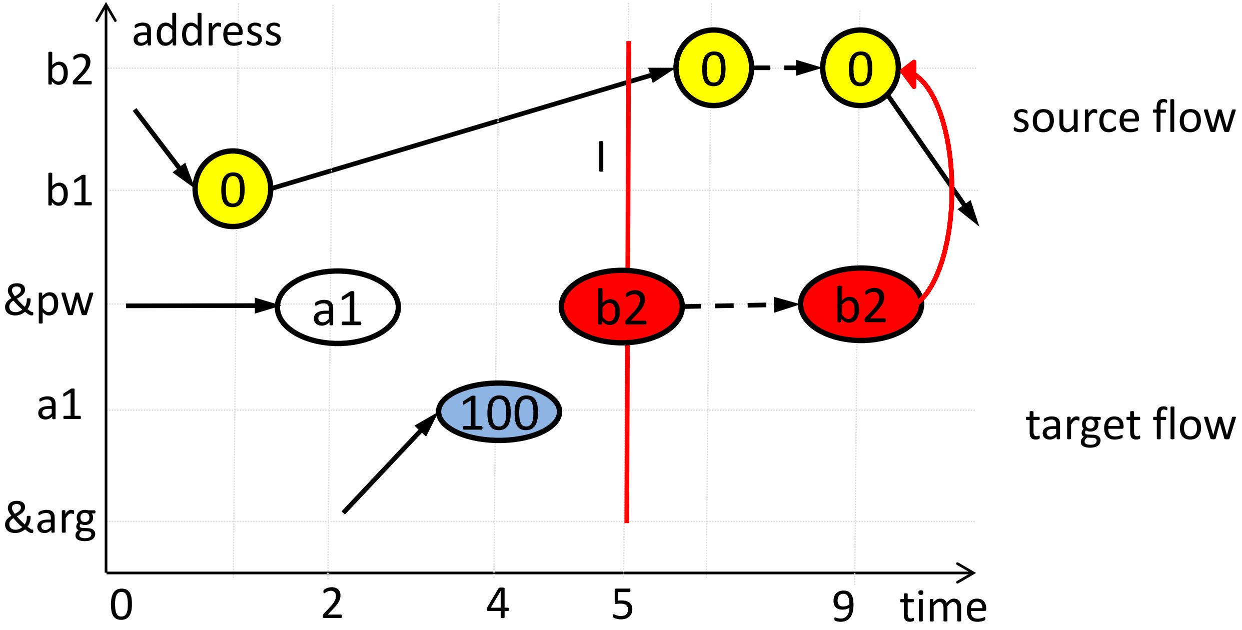

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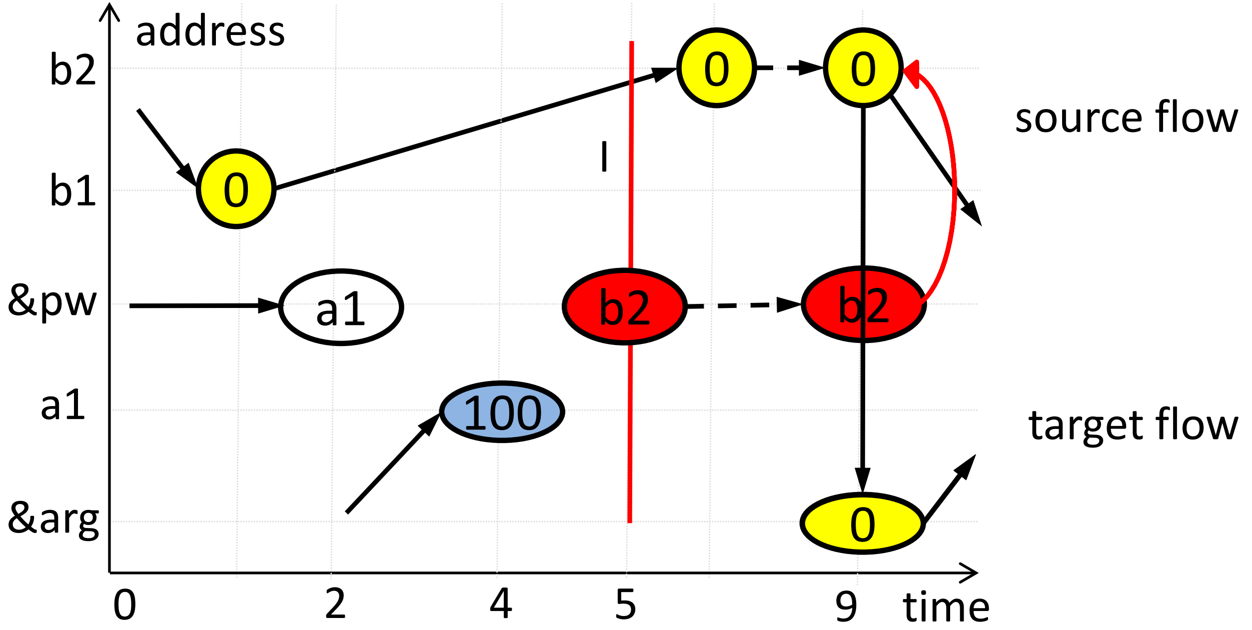

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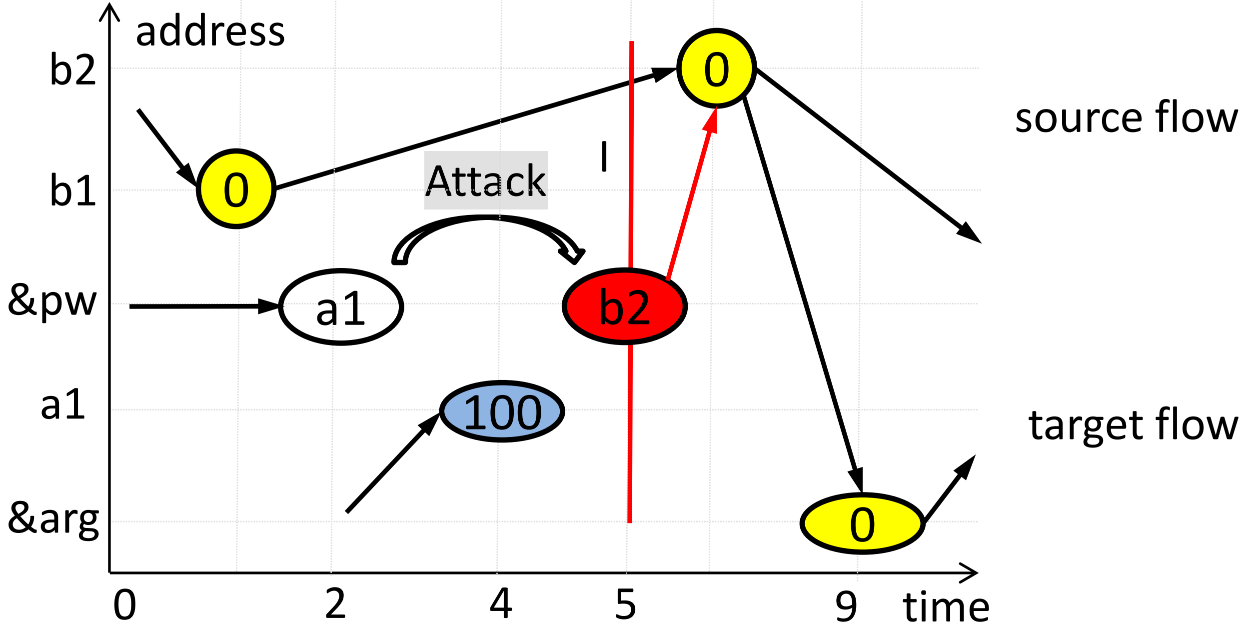

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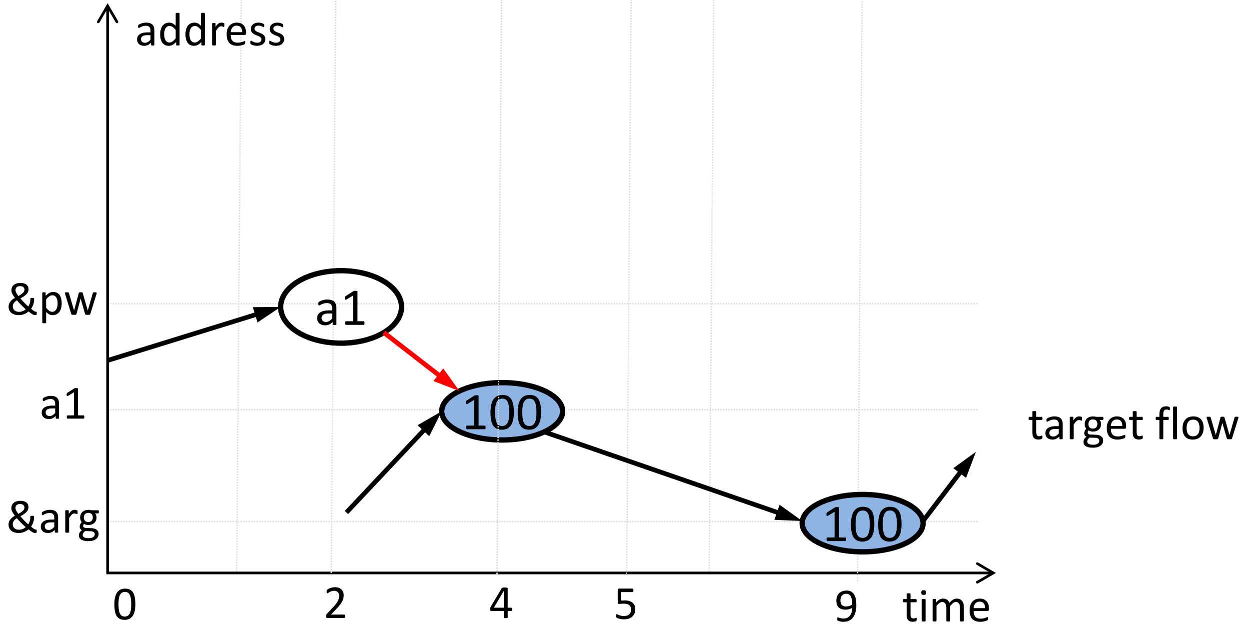

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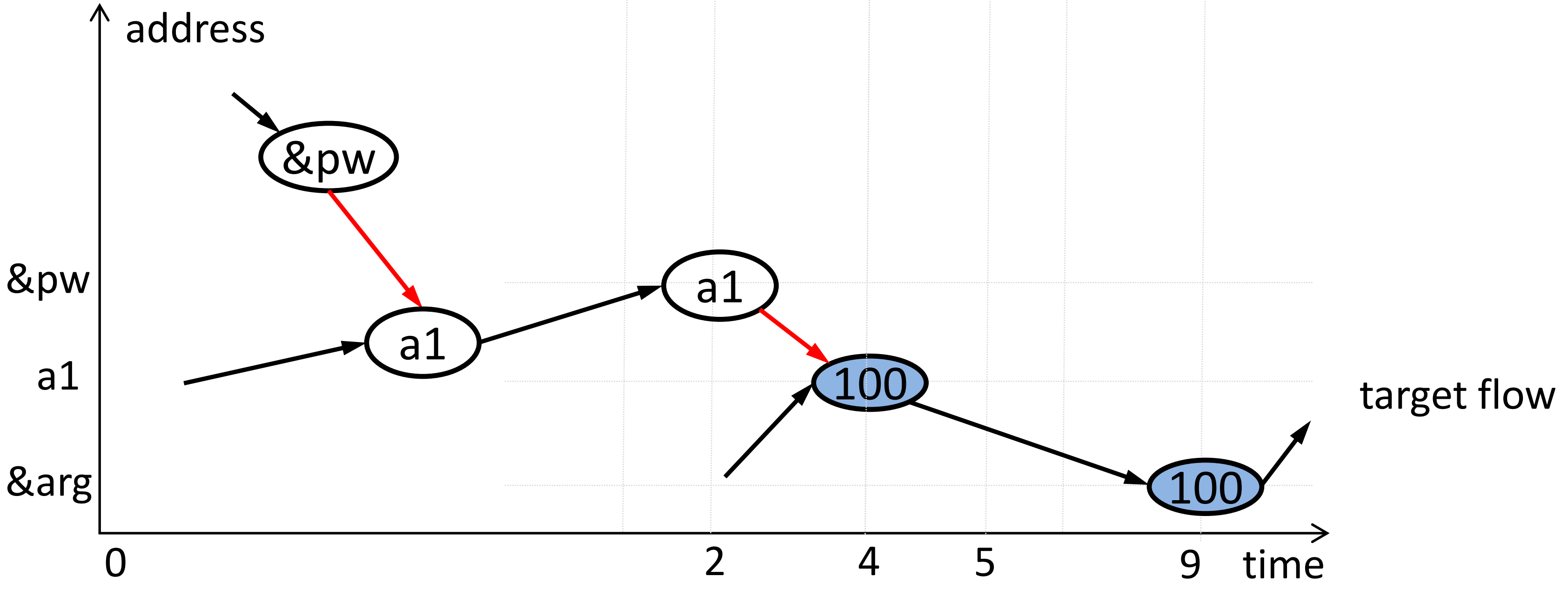

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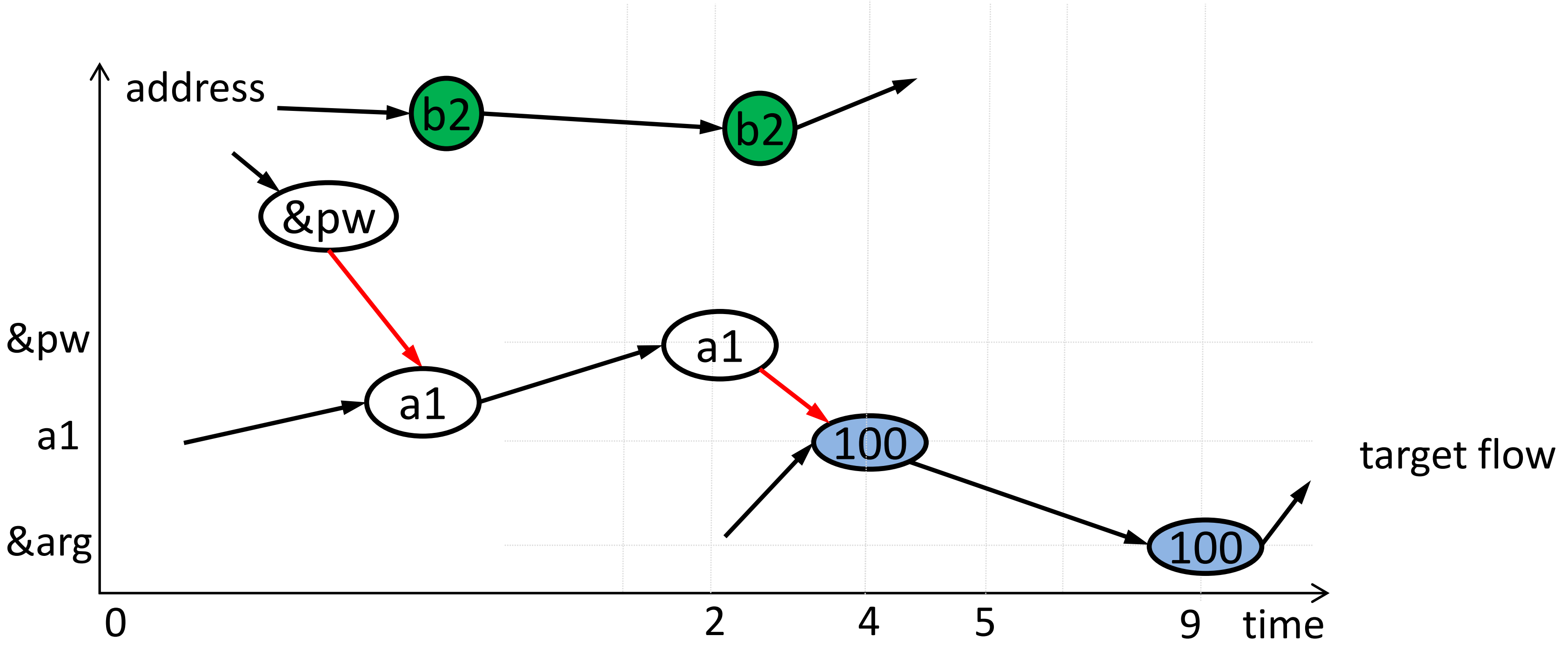

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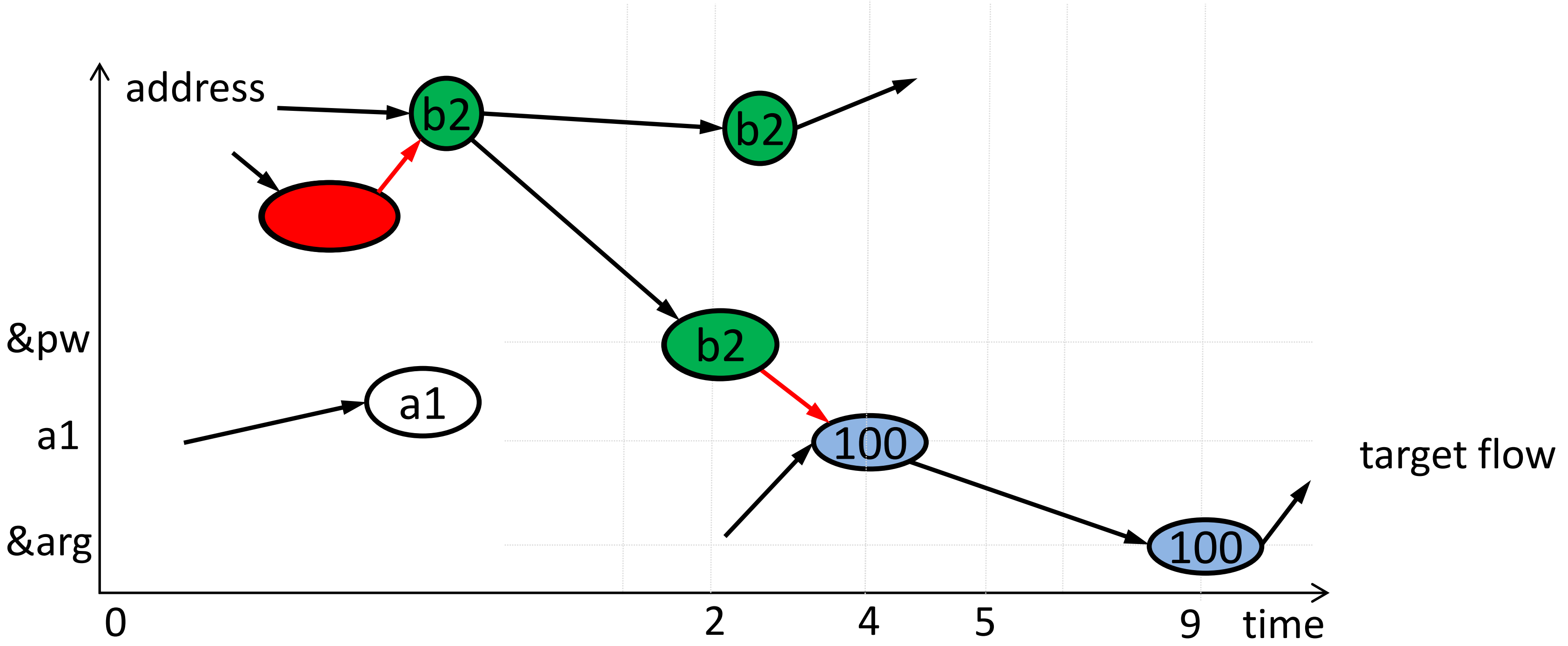

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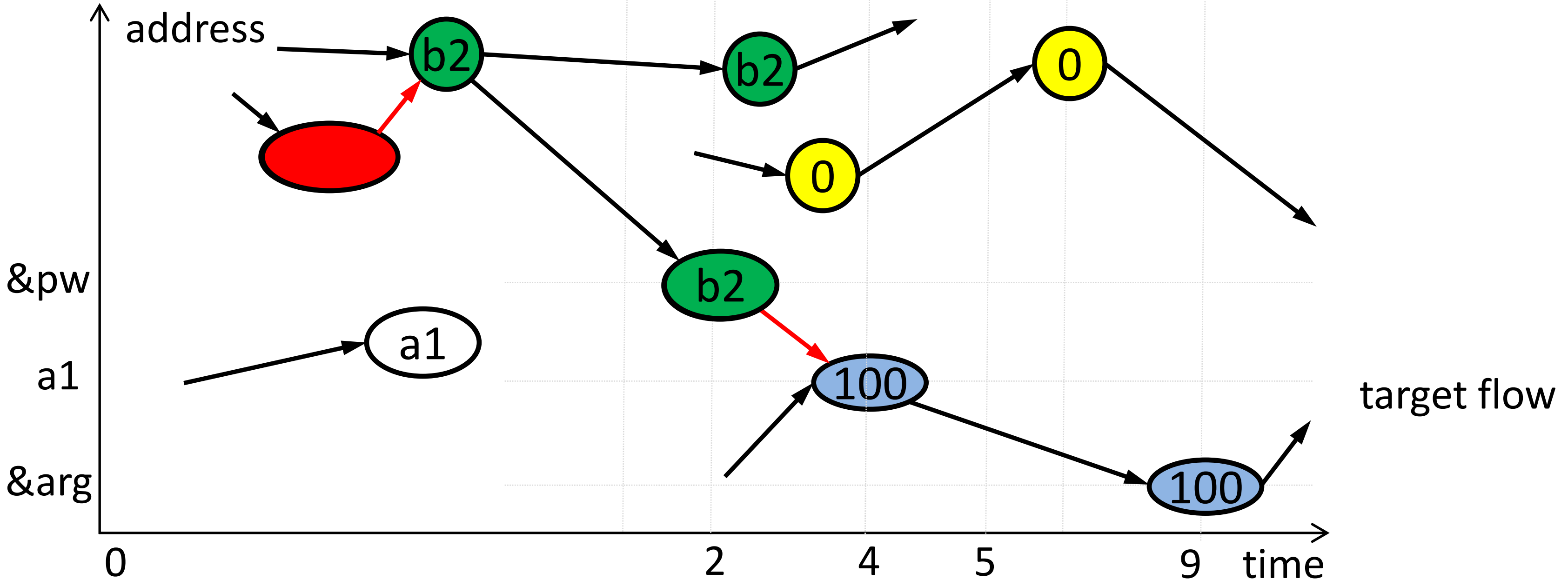

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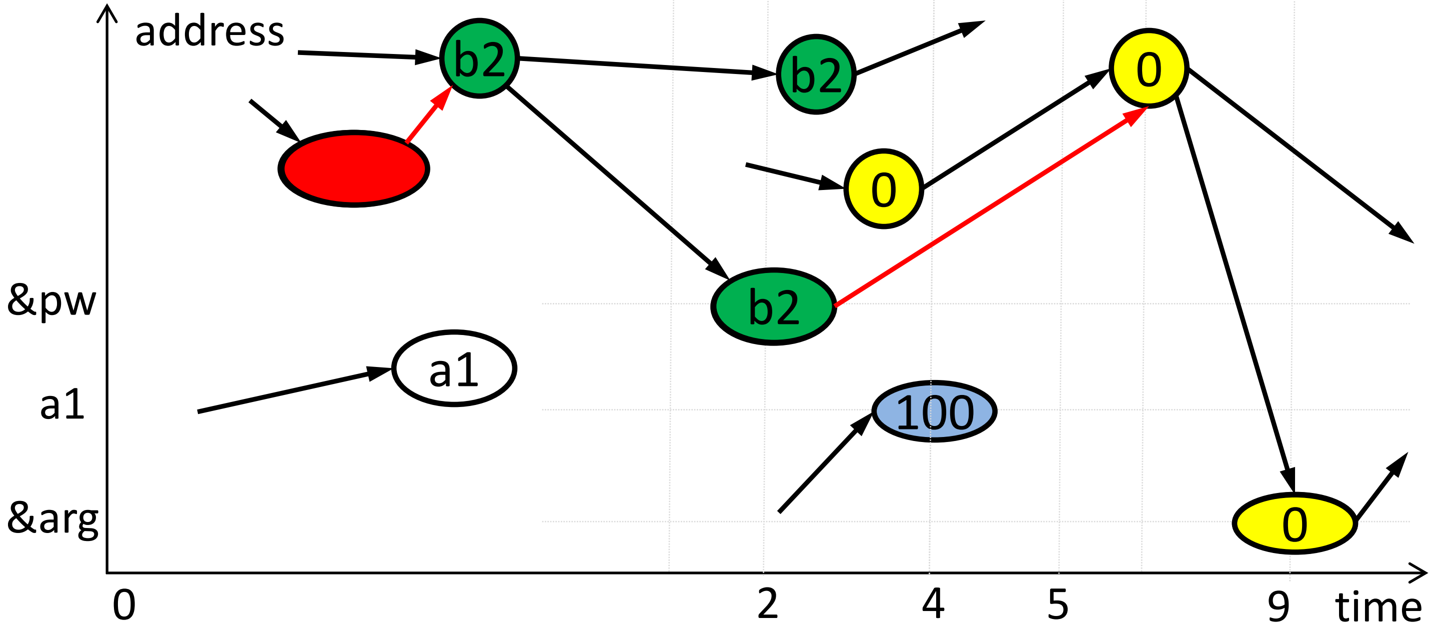

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- Multi-flow stitching
  - Intermediate data flows
  - Source flow -> flow 1 -> flow 2 -> … -> Target flow

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- Partial resue: offset is fixed

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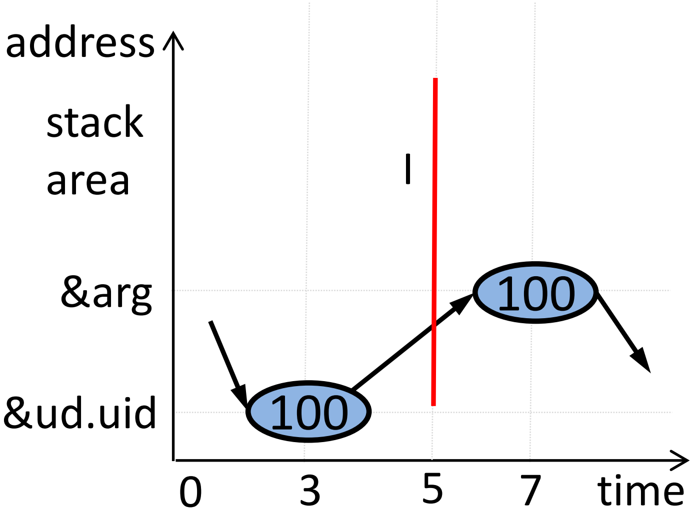

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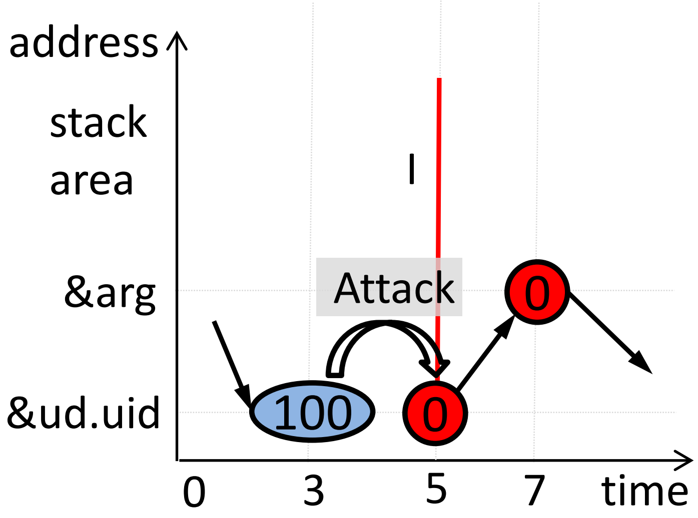

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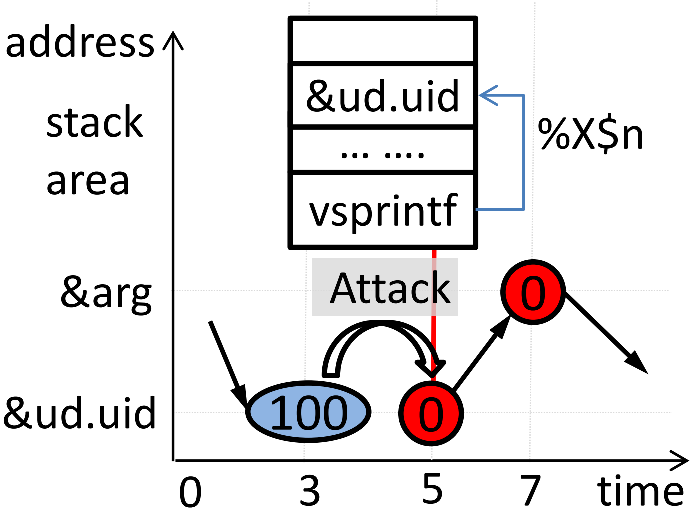

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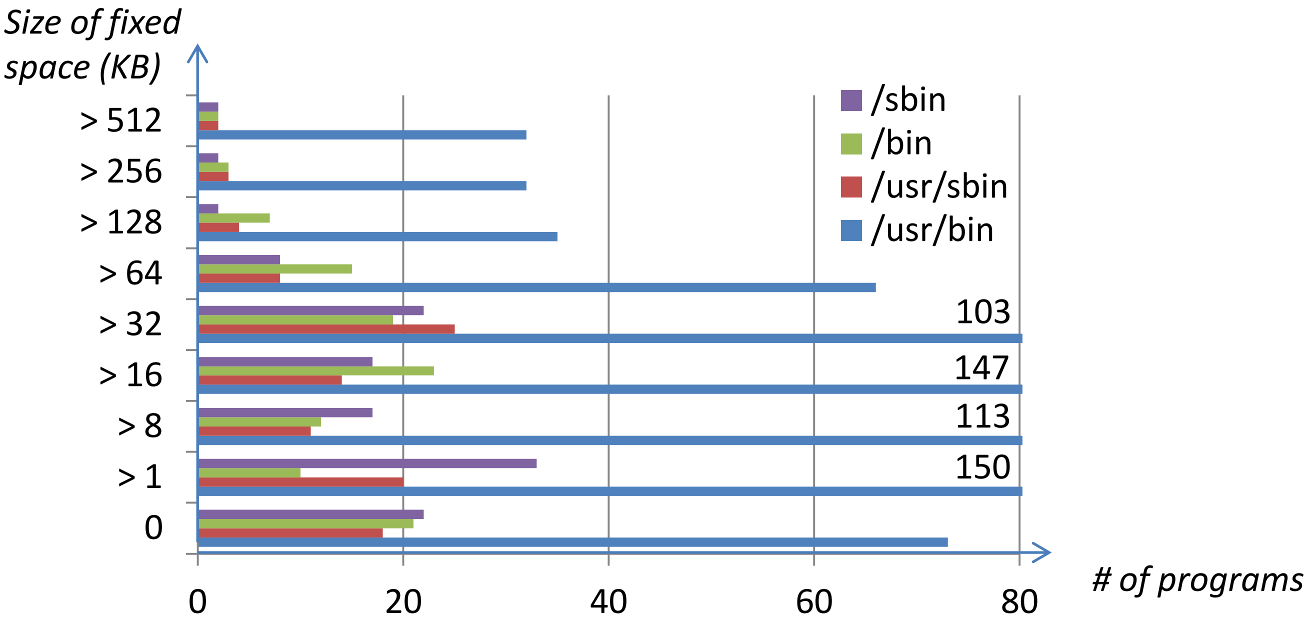

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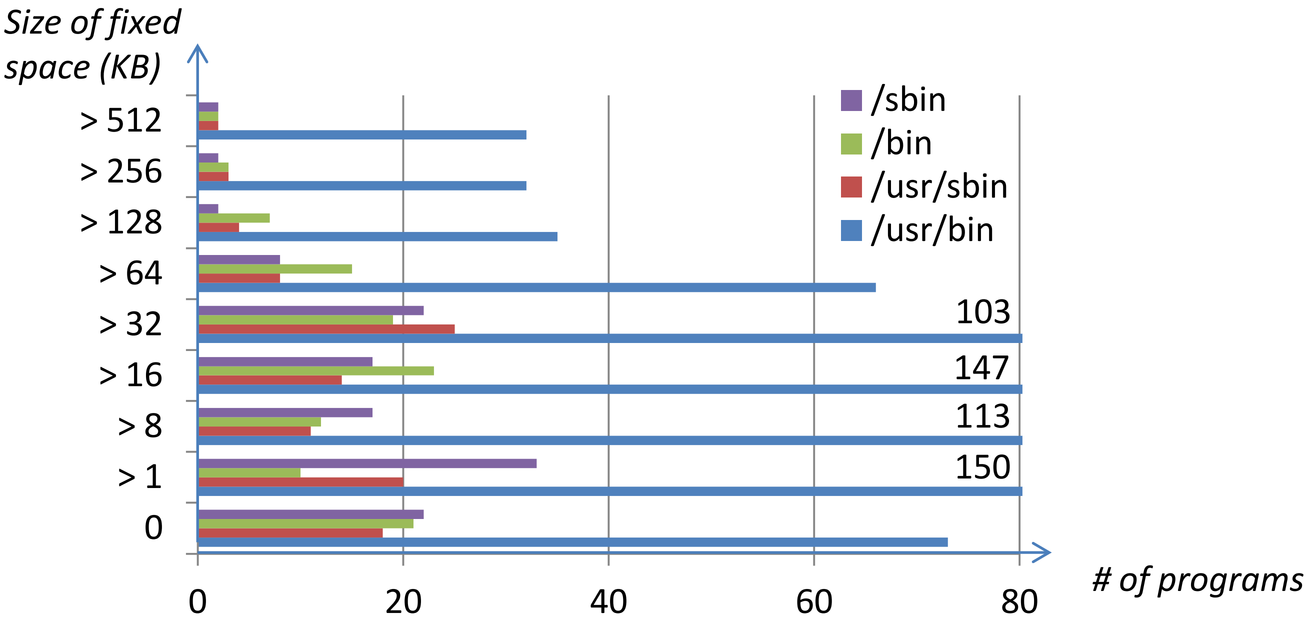
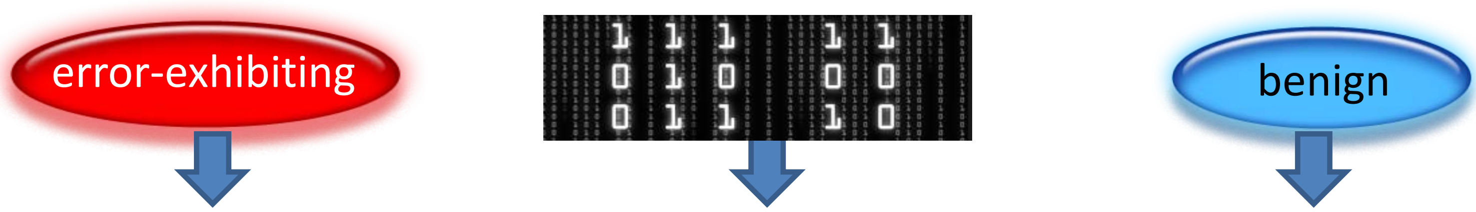
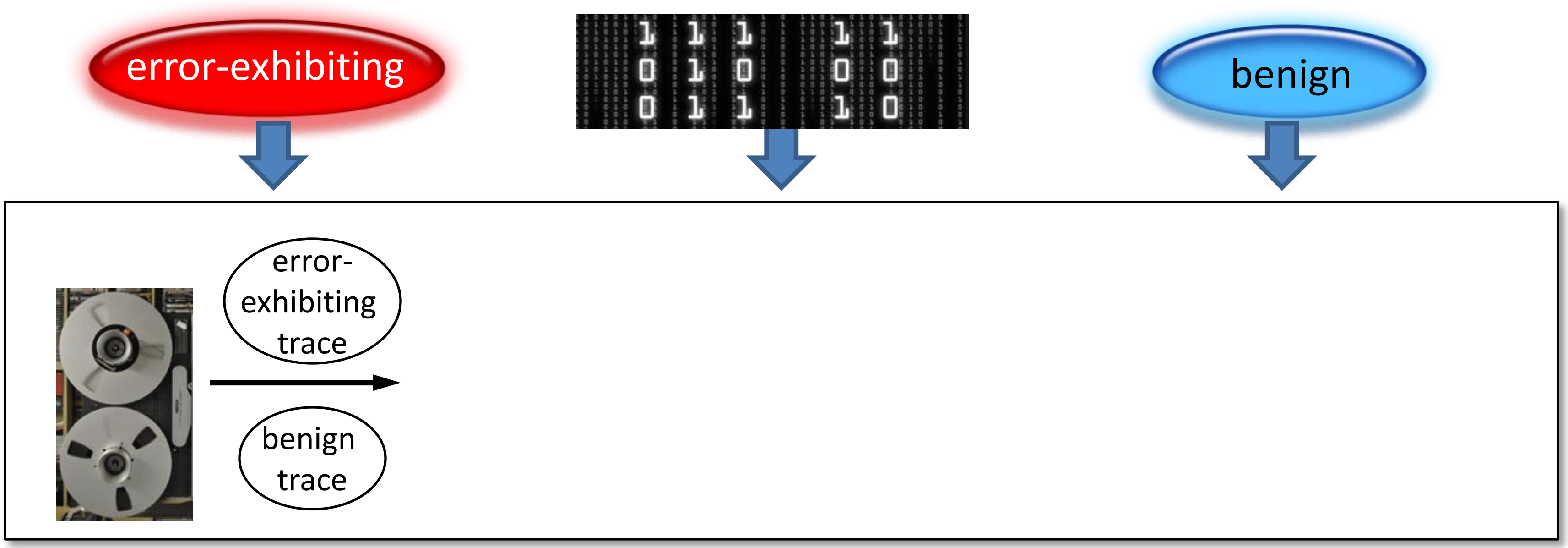


  - msvcr71.dll, hxds.dll on Windows

FlowStitch



FlowStitch


error-exhibiting
benign
error-exhibiting trace
benign trace

FlowStitch

error-exhibiting

benign

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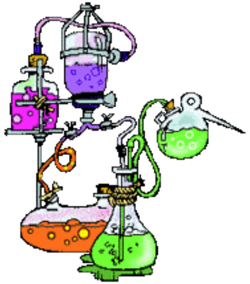

constraints, influence

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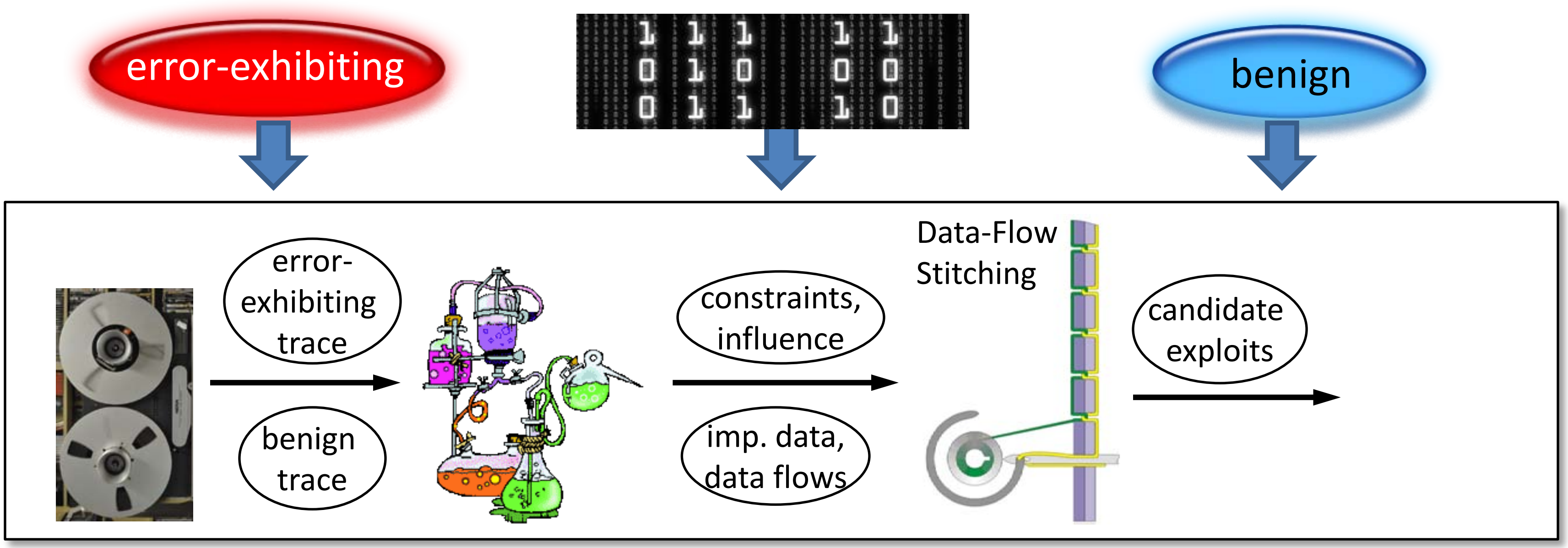

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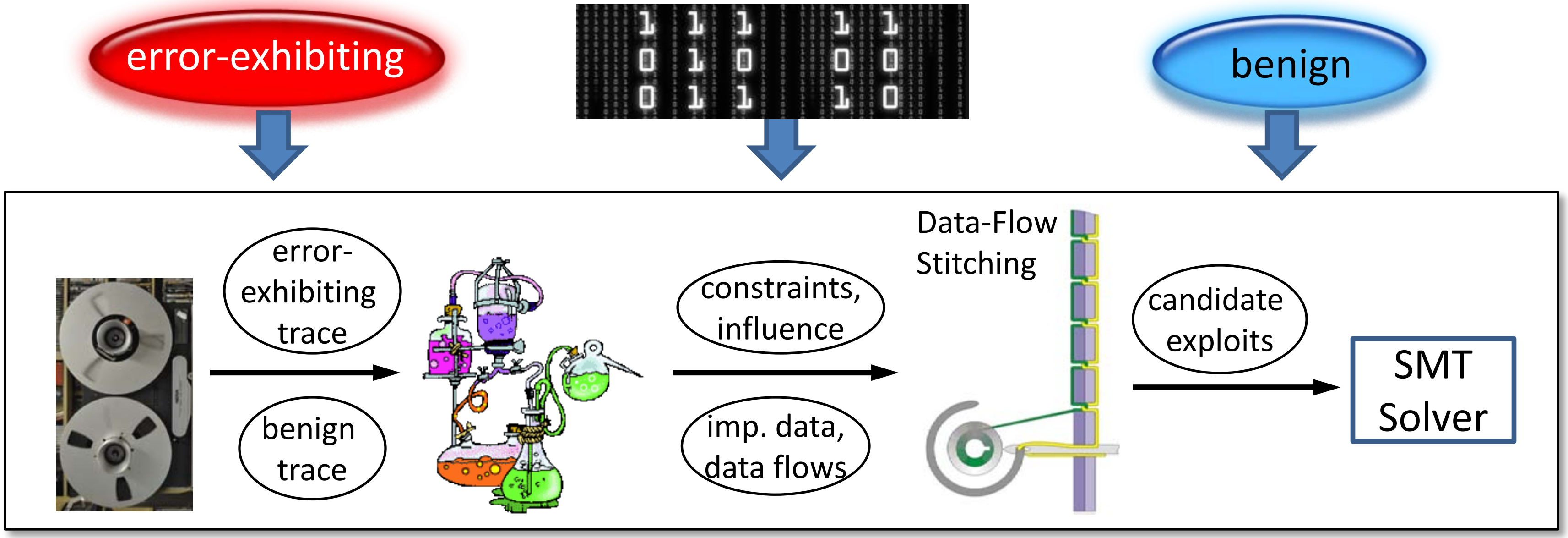
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1 1 1 1 1
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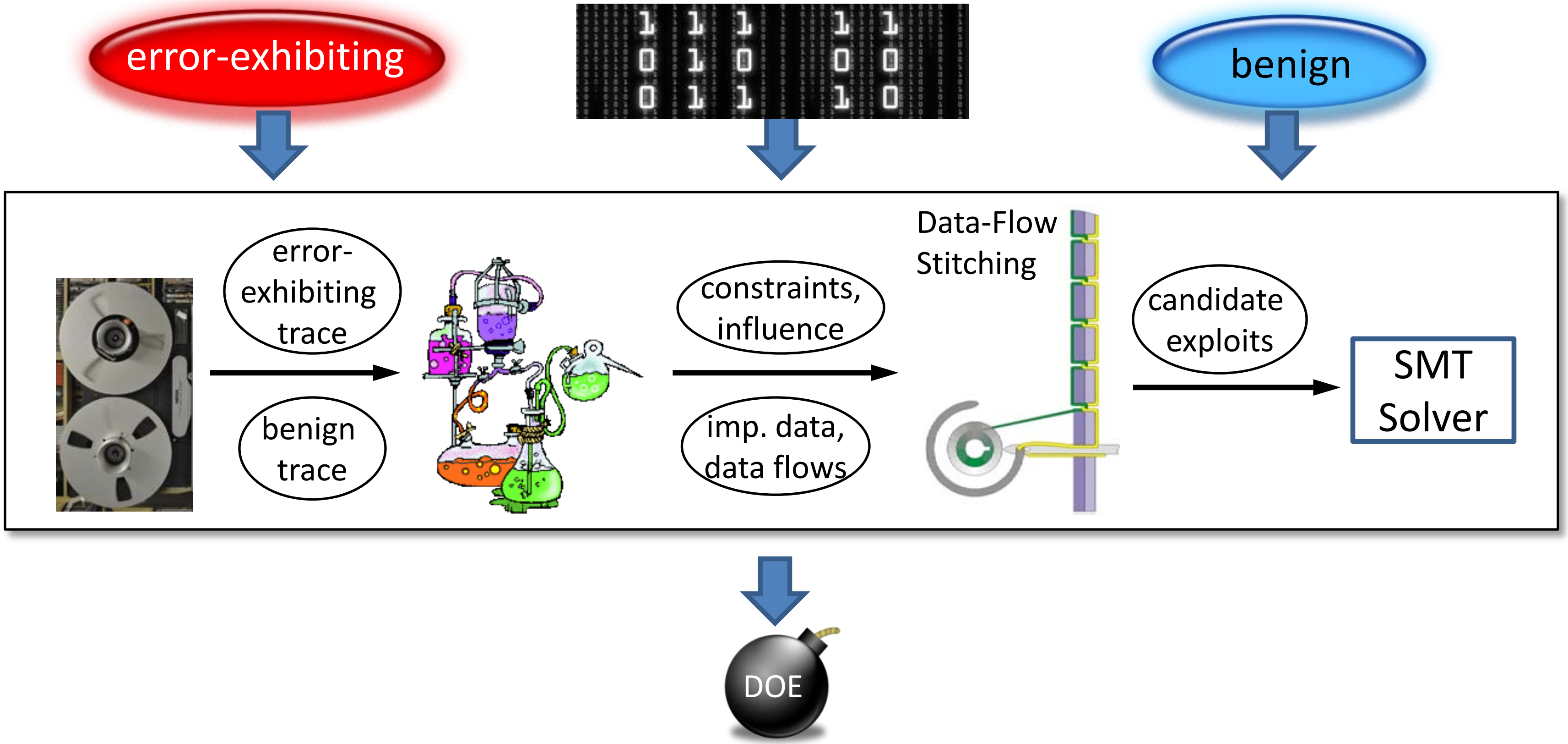
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DOE

Evaluation --- Generated Exploits

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			M_1: authenticated flag	
CVE-2000-0573 *	wu-ftpd	Format string	L_0: env variables	
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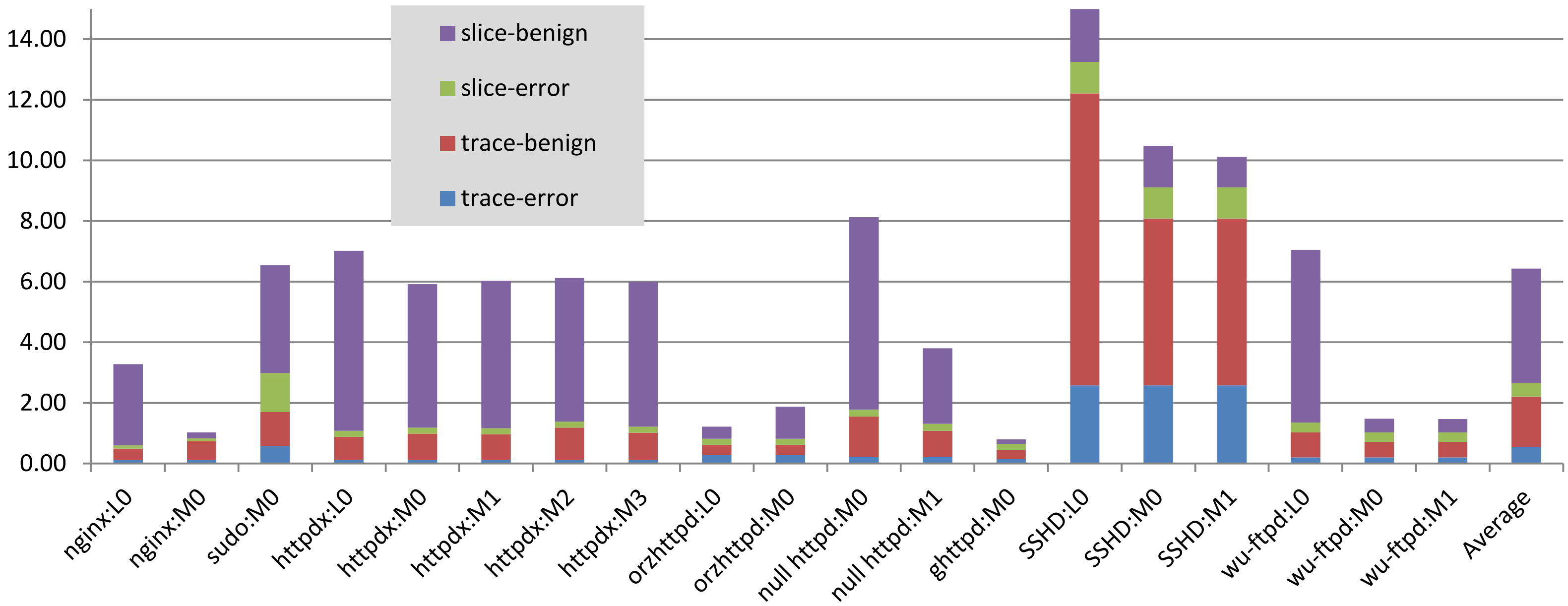
- 7 advanced stitch
  - 2-level stitch
- 10 bypass ASLR
  - 8 fixed addresses
  - 2 address reuse

Evaluation --- Performance



- 6.5 min/exploit
- Slice takes long
  - faster version is available (binary version)

Case Study – 2-Level Stitch

- *ghttpd* web server: stack buffer overflow

//serveconnection():
char *ptr; //URL pointer
//esi is allocated for it
1: if(strstr(ptr,"/.."))
reject the request;
2: **log**(...);
3: exec(ptr);
	Assembly of log(...)
	push %ebp
	push %esi
	// stack overflow
	pop %esi
	pop %ebp
	ret
		Assembly of line 3:
		
		push %esi
		…
		call <exec@plt>

- Previous exploit[1]
  - Corrupt pointer ptr: *(ptr) -> url

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```
Assembly of line 3:
  mov  -0xc(%ebp), %esi
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- Previous exploit[1] does not work any more
  - Corrupt pointer ptr: *(ptr) -> url

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		`push %esi`
		`…`
		`call <exec@plt>`

- Previous exploit[1] does not work any more
  - Corrupt pointer ptr: *(ptr) -> url
- We build a 2-level stitch
  - Corrupt pointer saved ebp: *(*(saved ebp)) -> *ptr -> url

Case Study – Sensitive Data Lifespan

- *SSHD* hashed key info leak
- *getspnam()* in *glibc* gets hashed key (heap copy) 
- *SSHD* copies hashed key to local stack (stack copy) 

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- *SSHD* copies hashed key to local stack (stack copy)

  - Overwritten by later usage
- *Challenging* to make lifespan correct!

Conclusion

- Rich Category: Data-Oriented Exploits
  - Single-edge stitch, Pointer stitch
  - N-level stitch, Multi-flow stitch
- Data Flow Stitching
  - Systematic way to generate data-oriented exploits
  - Agnostic to CFI, DEP and often ASLR
- Automatic construction is feasible

Thanks!

Hong Hu

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http://www.comp.nus.edu.sg/~huhong/