Boundless Memory Blocks

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Motivation

- Buffer overflows – the most common cause of security vulnerabilities
  - Majority of CERT reports are related to buffer overflows
  - Costs estimated in the billions of dollars

Memory Errors

- Buffer overflow attacks due to memory errors:
  - Usually on the call stack
  - But also on the heap

Safe C compilers

- Instrument the program with dynamic checks to detect illegal memory accesses
- When a buffer overflow is detected, program terminates with an error message

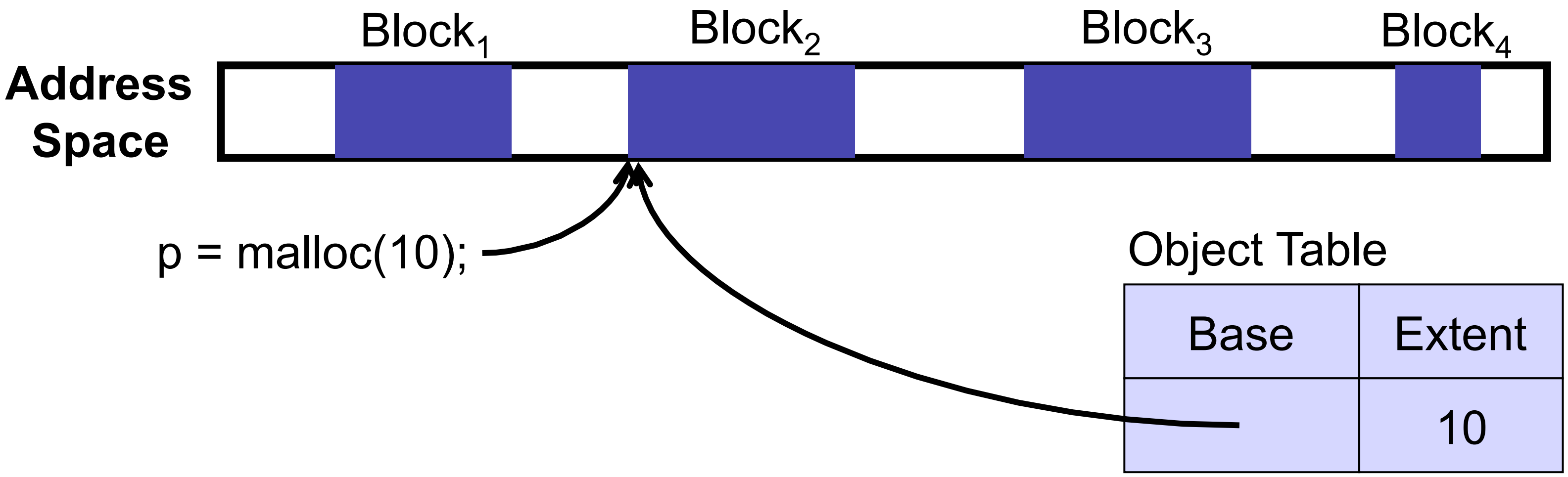
Continued Execution

- Detection critical, sometimes not the whole story
  - Terminating the program can be disruptive
  - Doesn’t address denial of service attacks
- **Focus on continued execution**
- **Through memory errors**

Our Technique

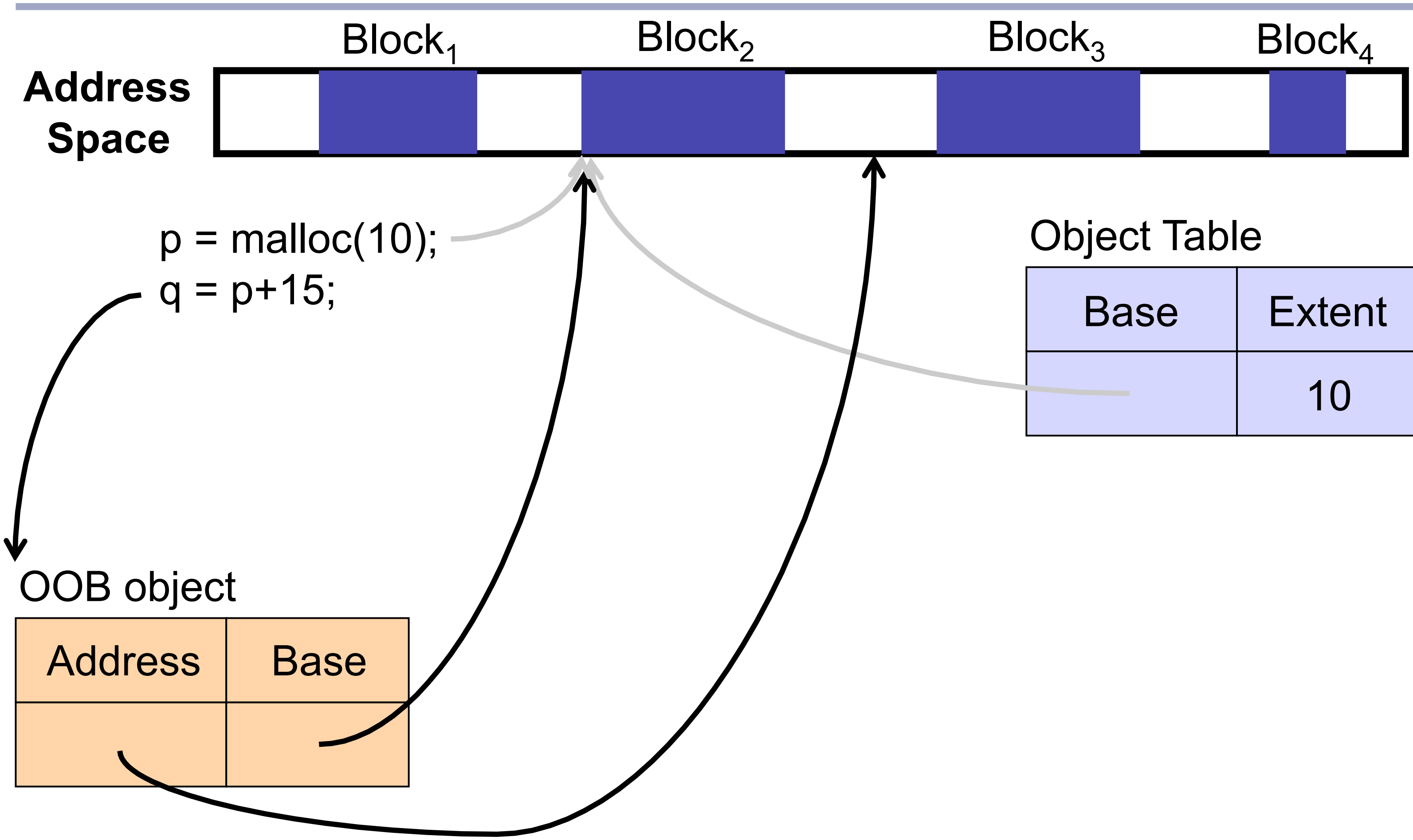
- Detect out of bounds writes
- Store values in a hash table
- Return values for corresponding reads

CRED



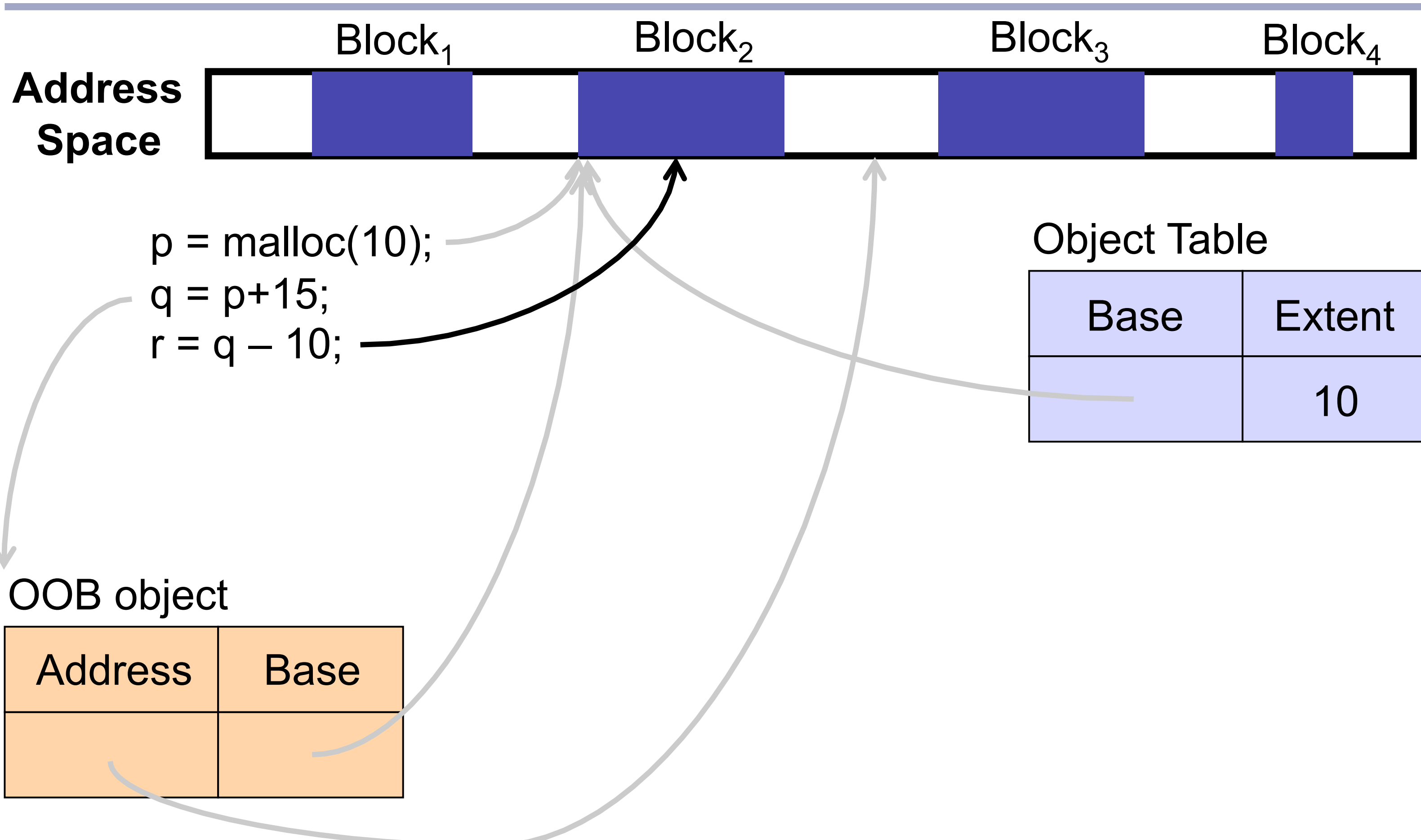
Block1
Block2
Block3
Block4
Address Space
p = malloc(10);
Object Table
Base
Extent
10

CRED

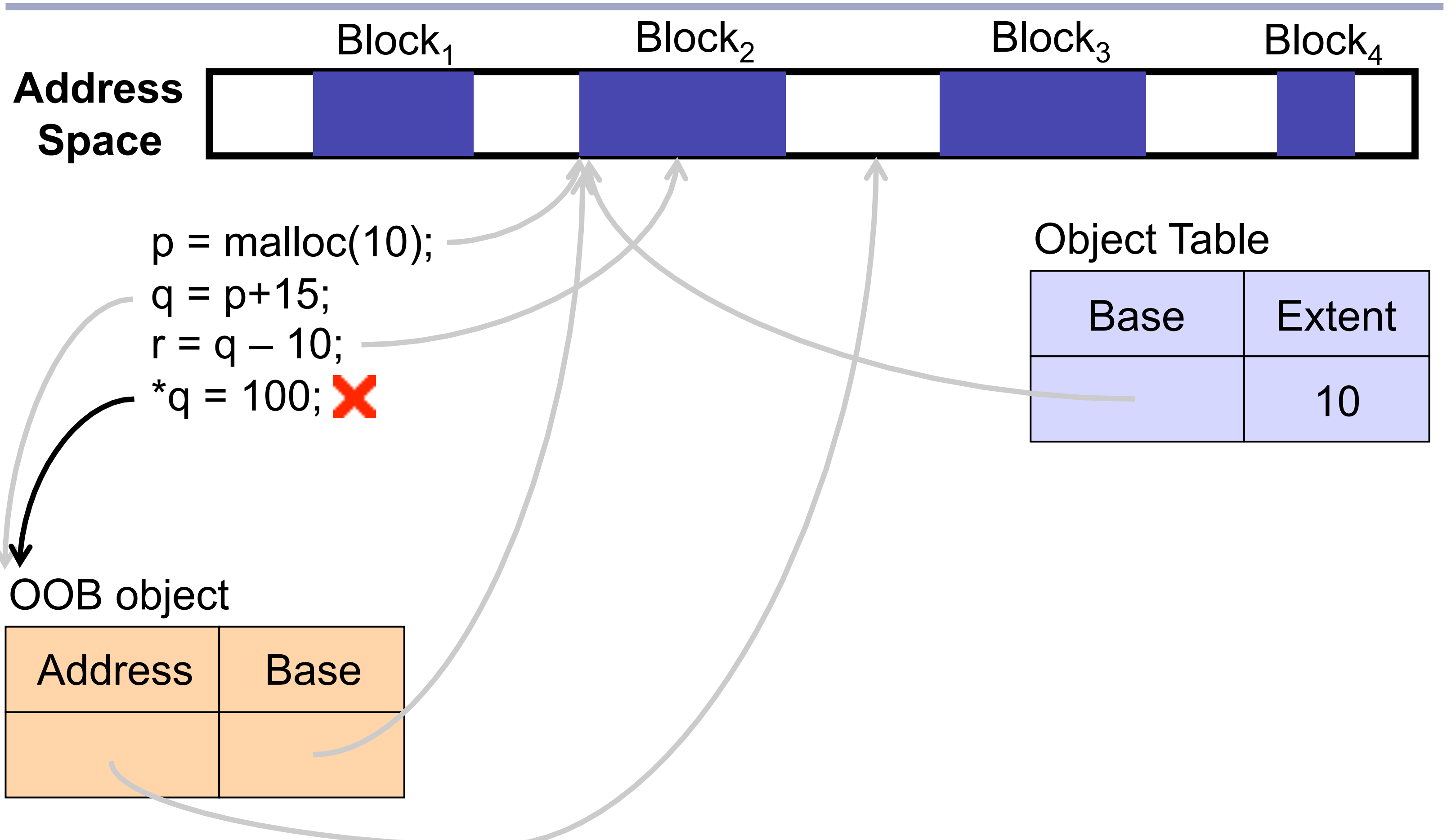


Block1
Block2
Block3
Block4
Address Space
p = malloc(10);
q = p+15;
Object Table
Base
Extent
10
OOB object
Address
Base

CRED

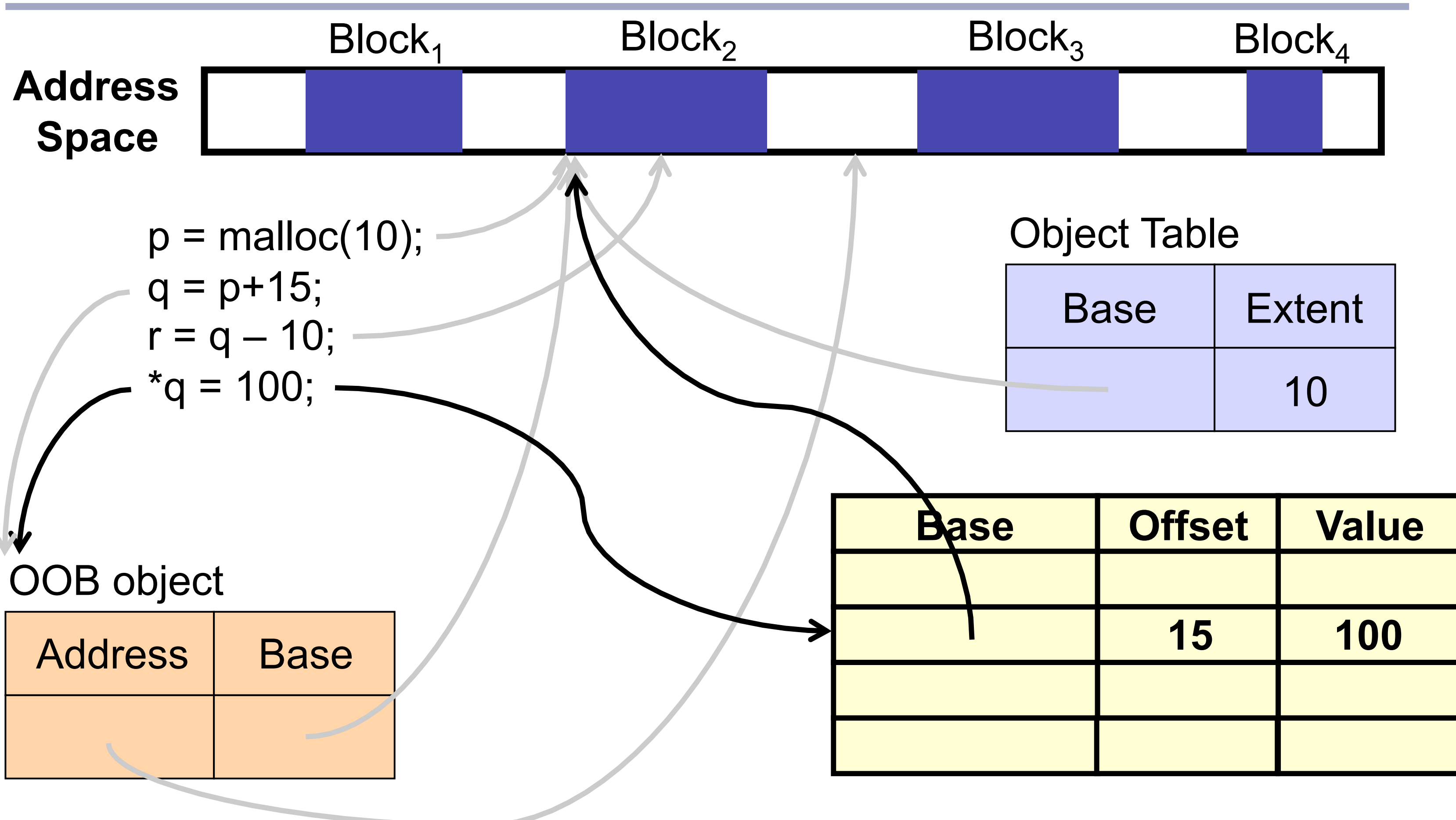

Block$_1$
Block$_2$
Block$_3$
Block$_4$
Address Space
p = malloc(10);
q = p+15;
r = q – 10;
Object Table
Base
Extent
10
OOB object
Address
Base

CRED

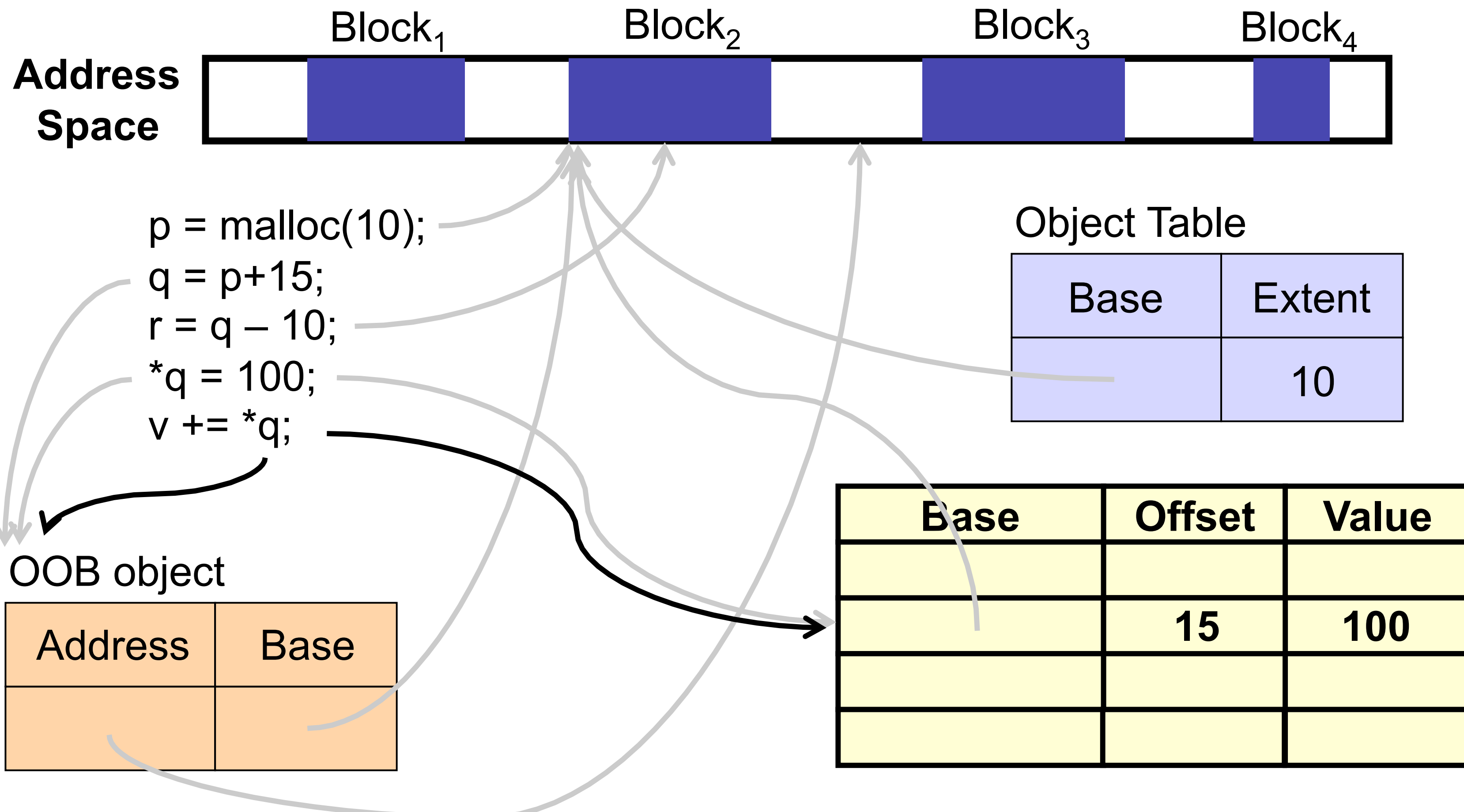


Block1
Block2
Block3
Block4
Address Space
p = malloc(10);
q = p+15;
r = q – 10;
*q = 100;
Object Table
Base
Extent
10
OOB object
Address
Base

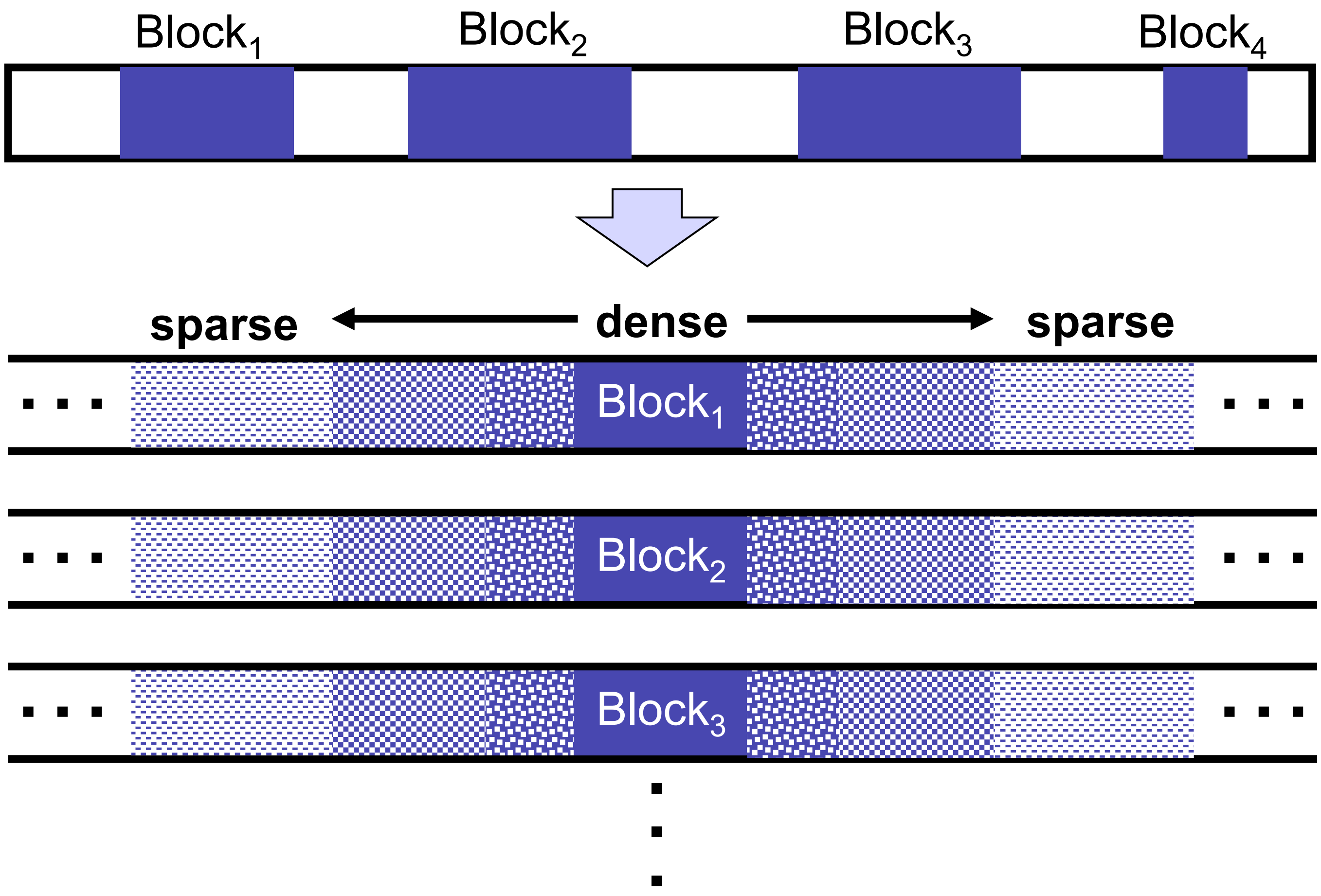
BMB Compiler



BMB Compiler



Net Effect of Our Technique



Possible Problems

- New DOS attack
  - Craft an input which will cause a large number of writes
  - Solution: treat the hash table as a fixed-size cache using the LRU replacement policy

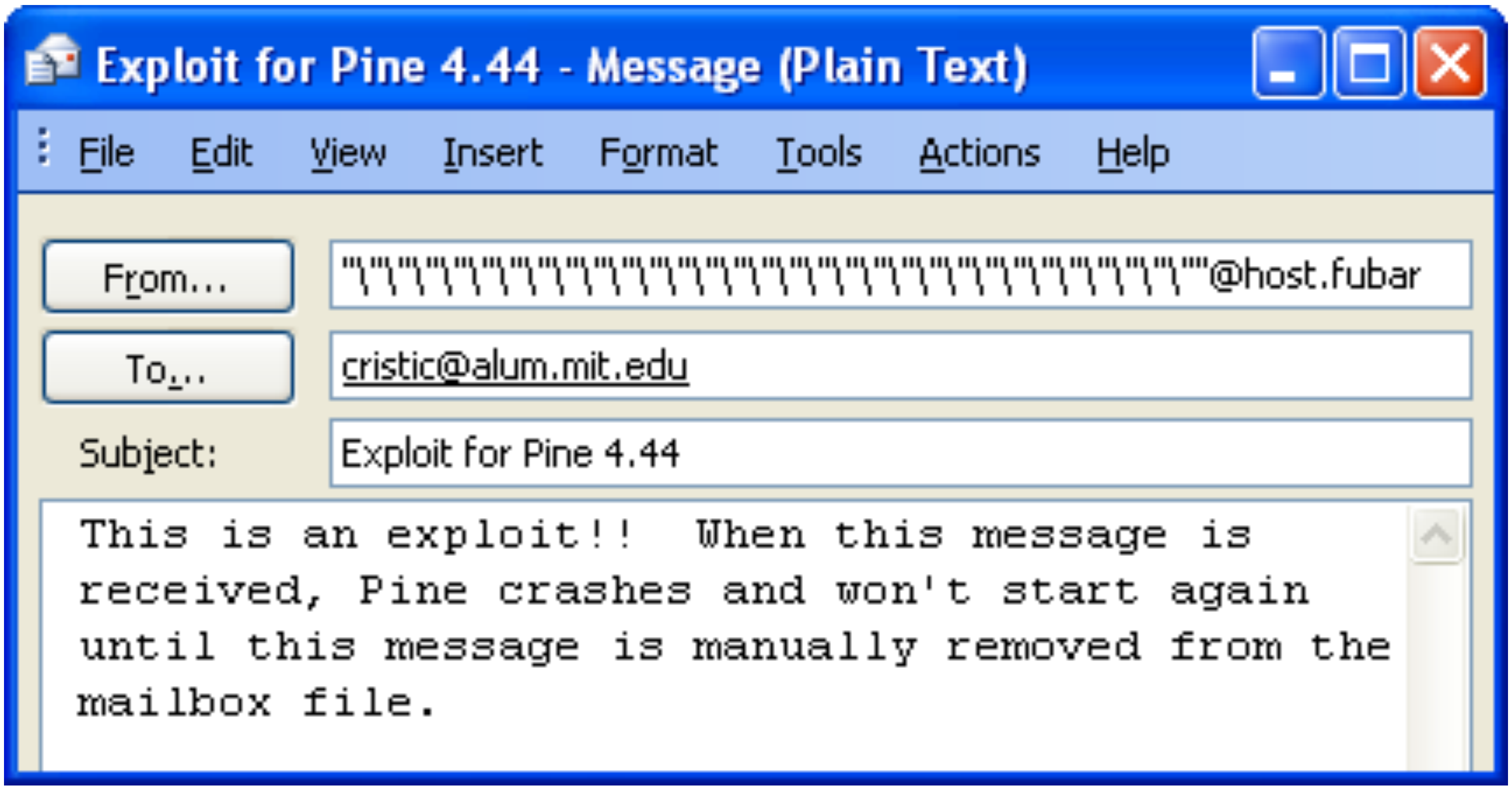
Possible Problems (cont.)

- Cache Misses
  - Bounded number of OOB writes?
  - Haven’t triggered cache misses in our benchmarks
  - But may be a serious problem
- Uninitialized reads
  - Found in Midnight Commander
  - Automatic zero-initialization

Evaluation

- Tested several open source programs
  - Servers: Apache, Sendmail
  - Mailers: Pine, Mutt
  - Utilities: Midnight Commander
- On publicized buffer overflow security vulnerabilities
  - SecuriTeam, Security Focus

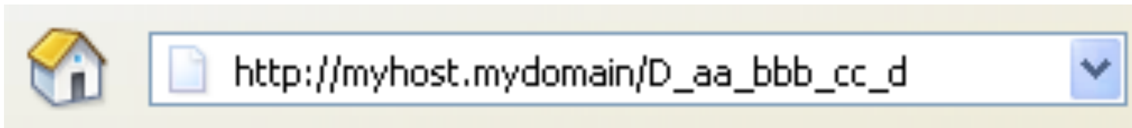
Vulnerabilities – Pine 4.44



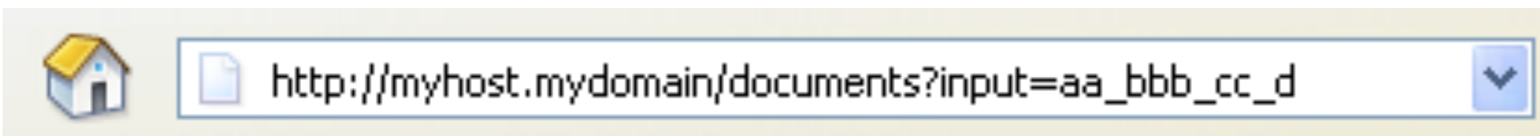
Vulnerabilities – Apache 2.0.47

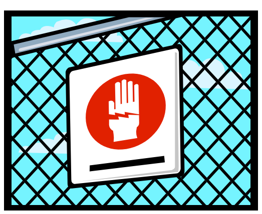
- Apache can redirect some URLs, which are specified by regular expressions
- Example: redirect URLs of the form *http://myhost.mydomain/D_(a*)_(b*)_(c*)_(d*)* to URLs of the form *http://myhost.mydomain/documents?input=$1_$2_$3_$4*

Vulnerabilities – Apache 2.0.47



D_(a*)_(b*)_(c*)_(d*) →
documents?input=$1_$2_$3_$4





Static buffer contains space for only 10 parenthesized captures!

Evaluation (cont.)

- Three versions per benchmark
  - GCC (Standard Compilation)
  - CRED (Bounds Check Compilation)
  - BMB (Boundless Memory Blocks Compilation)
- Tested each versions on the acquired vulnerabilities

Results

	Secure		
	GCC	CRED	BMB
Pine	✗	✓	✓
Mutt	✗	✓	✓
Apache	✗	✓	✓
Sendmail	✗	✓	✓
MC	✗	✓	✓

Results

	Secure			Continues Correctly		
	GCC	CRED	BMB	GCC	CRED	BMB
Pine	✗	✓	✓	✗	✗	✓
Mutt	✗	✓	✓	✗	✗	✓
Apache	✗	✓	✓	✓ (yellow)	✓ (yellow)	✓
Sendmail	✗	✓	✓	✗	✗	✓
MC	✗	✓	✓	✗	✗	✓

Results

	Secure			Continues Correctly			Initializes		
	GCC	CRED	BMB	GCC	CRED	BMB	GCC	CRED	BMB
Pine	✗	✓	✓	✗	✗	✓	✓ (yellow)	✓ (yellow)	✓
Mutt	✗	✓	✓	✗	✗	✓	✓ (yellow)	✓ (yellow)	✓
Apache	✗	✓	✓	✓ (yellow)	✓ (yellow)	✓	✓	✓	✓
Sendmail	✗	✓	✓	✗	✗	✓	✓	✗	✓
MC	✗	✓	✓	✗	✗	✓	✓	✓ (yellow)	✓

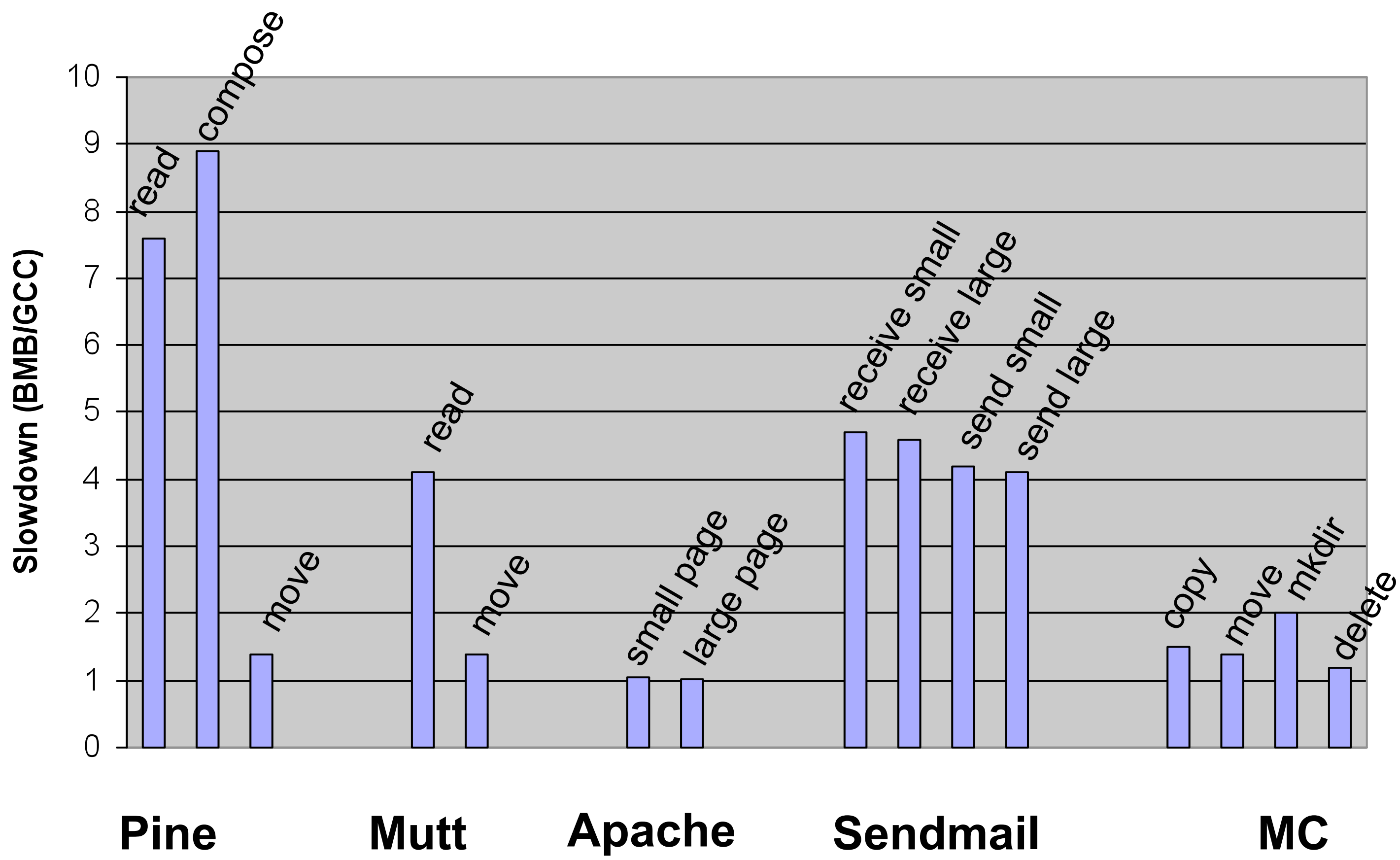
Results

	Secure			Continues Correctly			Initializes			Correct For Attack		
	GCC	CRED	BMB	GCC	CRED	BMB	GCC	CRED	BMB	GCC	CRED	BMB
Pine	✗	✓	✓	✗	✗	✓	✓ (yellow)	✓ (yellow)	✓	✗	✗	✓
Mutt	✗	✓	✓	✗	✗	✓	✓ (yellow)	✓ (yellow)	✓	✗	✗	✓
Apache	✗	✓	✓	✓ (yellow)	✓ (yellow)	✓	✓	✓	✓	✗	✗	✓
Sendmail	✗	✓	✓	✗	✗	✓	✓	✗	✓	✗	✗	✓ (yellow)
MC	✗	✓	✓	✗	✗	✓	✓	✓ (yellow)	✓	✗	✗	✓ (yellow)

Decoupled Errors

- Developers may incorrectly calculate the size of a buffer
  - Hard to reason about the worst case, which is usually exploited by security attacks
- But the rest of code is correct
  - Although the programmer failed to allocate enough space, the program usually correct when provided with (conceptually) unbounded memory blocks.

Performance



Related Work – Continued Execution

- Failure Oblivious Computing [Rinard et al, OSDI 2004]
- Execution Transactions [Sidiroglou et al, Columbia Univ. TR 2004]
- BMB compiler generates anticipated and correct executions, but is less general

Related Work – Safe C Compilers

- Jones and Kelly [AADEBUG 1997], enhanced by Ruwase and Lam [NDSS 2004]
- Austin et. al [PLDI 1994]
- Yong and Horwitz [FSE 2003]
- Necula et al [POPL 2002]
- Jim, Morrisett et al [USENIX 2002]

Buffer Overflow Detection Tools

- StackGuard [Cowan et al, USENIX 1998]
- StackShield [http://www.angelfire.com/sk/stackshield/]
- Purify [Hastings and Joyce, USENIX 1992]
- Program shepherding [Kiriansky, Bruening, Amarasinghe, USENIX 2002]
- Rebooting, checkpointing, manual error detection and repair etc.

Extensible Arrays

- Many languages provide some form of extensible arrays – e.g. Java
- BMB
  - Preservation of the address space from the original implementation
  - Efficiency – allocates only elements which are actually accessed
  - Avoids denial of service attacks

Conclusion

- Boundless Memory Blocks
  - Eliminates security vulnerabilities and data structure corruption
  - Enhances availability
- Implementation
  - Store out of bounds writes in a hash table
  - Retrieve value from the hash table for out of bounds reads
- Net Effect
  - Give each data block its own address space
  - Address spaces dense in the middle, sparse everywhere else

Questions