CSE 451: Operating Systems
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Module 18
Meltdown

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Reading Kernel Memory from User Space

- Three parts
  - What is my cache? Pipelining and branch prediction.
  - Use timing to determine if something is in the cache or not.
  - A simple coding example to determine the value of a byte.

- A more complete description is in “Meltdown: Reading Kernel Memory from User Space”, Communications of the ACM, June 2020, Vol 63 No. 6, Pages 46-56.

Determining the value of a byte

- Consider this snippet of code to read a byte and use its value as an index into an array.

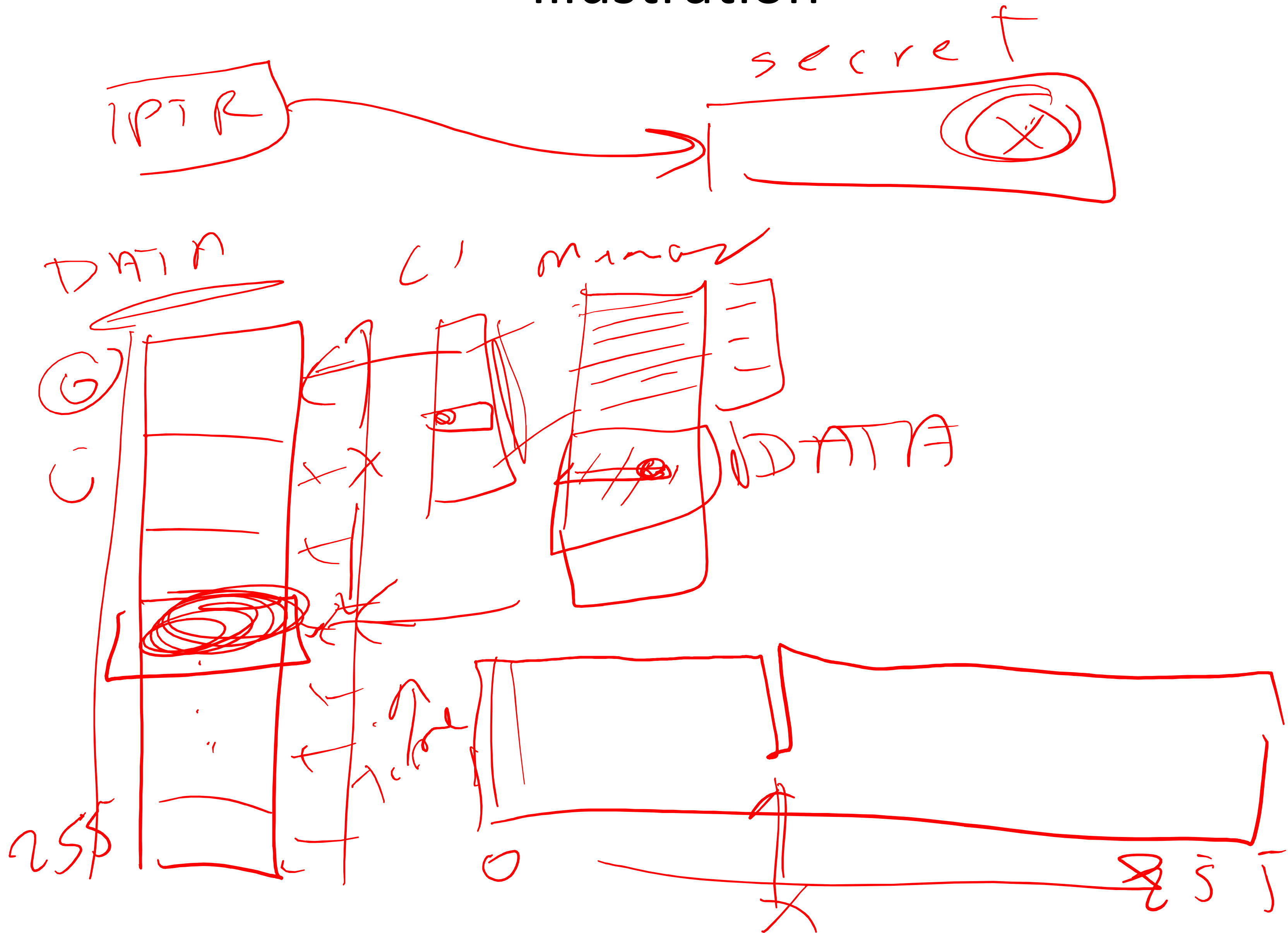
```
if (spec_cond) {  // teach the HW that this is true
   unsigned char value = *(unsigned char *)ptr;  // pointer to the secret
   maccess(&data[(value & 0xff)*0x100]);  // data is in my address space (stride of 256)
}
```

- Now determine what data item was accessed based on what is now in the cache. For each potential value record how long it takes to access the data.

```
time = rdtsc();
maccess(&data[value]);
delta = rdtsc() - time;
```

- The value with the fastest delta time exposes the secret.

Illustration



What can Ptr point to?

- What if ptr is a legal address? – works fine
- What if ptr is an illegal address? – raise an exception

Putting it all together

1. Teach the HW to predict the branch (may not be necessary given if the HW automatically does pipelining across branches).

2. Flush the cache, e.g., CFLUSH().

3. “Trick” the HW to do load the cache based on the secret value. But don’t raise an exception now by having spec_cond be FALSE.

4. Scan through memory to see what part of data was loaded into the cache.

5. Rinse and repeat.

Illustration

Possible fixes

Optimizations and caches work great, except when they don't or when they leak information.

1. Remove Cache, or branch prediction, or pipelining.

2. Don't rely on protection bit in the PTE to stop users from accessing kernel data, i.e., redo how the Operating System uses page tables.