A Concise Forwarding Information Base for Scalable and Fast Name Switching

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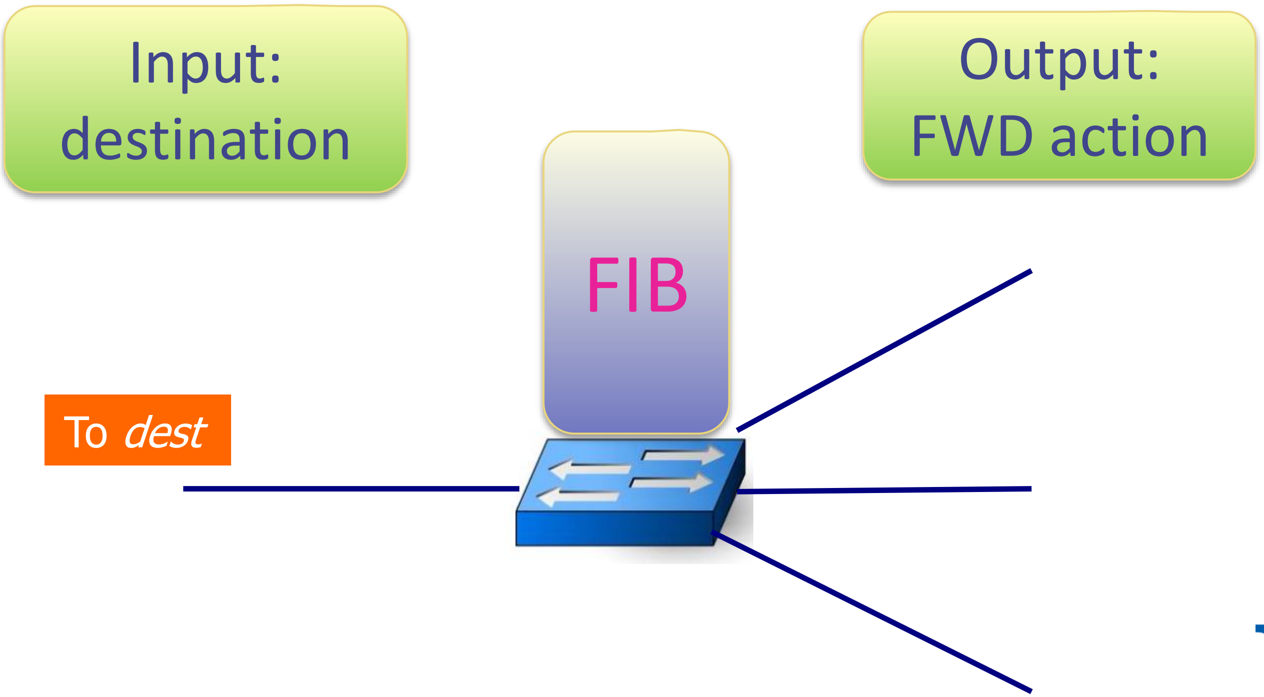
Forwarding Information Base (FIB)

A data structure (typically a table) in a network device to determine forwarding actions



Names vs. IP addresses

- (most) Names are flat, permanent, and location-independent
- Flexible network services for mobile devices and VMs: routing, firewall, VPN, etc.
- Flow IDs (Packet headers) can also be considered as names.
- Biggest problem: FIB explosion

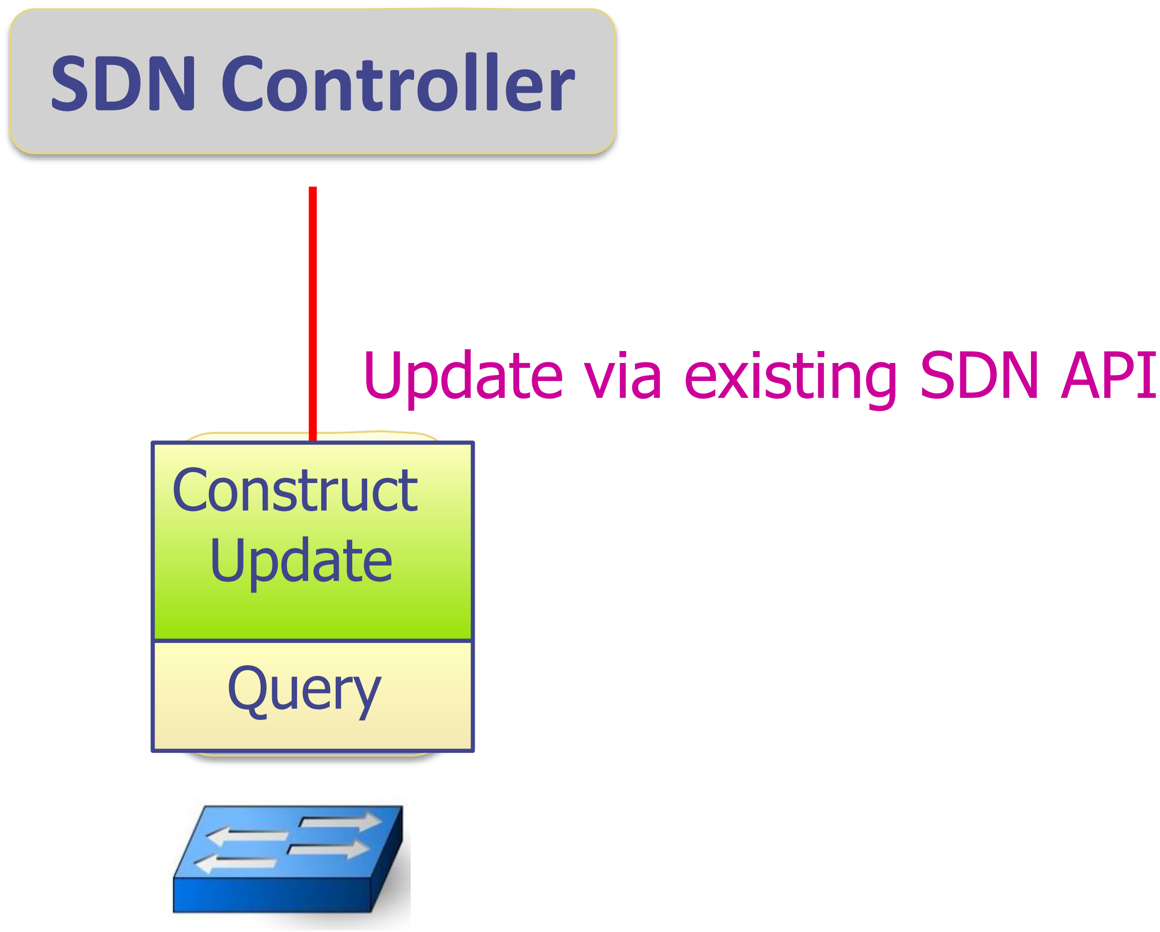
Examples of network names

- Enterprise and data center networks:
  - SEATTLE [SIGCOMM'08], VIRO [Infocom'11], ROME [ICNP'12]
- Future Internet Architecture (FIA)
  - Layered Naming Architecture [SIGCOMM'04], AIP [SIGCOMM'08]
  - NSF FIA projects: NDN, XIA, MobilityFirst
- LTE access network [SIGCOMM'15]

New FIB design: Concise

- 1. Use the least memory ever
  - Fast memory is expensive and power-hungry.
  - Only 10% - 30% of Cuckoo [CoNEXT'13, SIGCOMM'15]
- 2. Fast query speed ever
  - 2x to 5x advantage
- 3. Update speed slower than some FIBs
  - Still support millions of updates per second.

Idea of Concise



Optimize memory and query cost

Concise functions

- Classify *n* names into *d* different sets.
- Each set is a forwarding action

- Relying on a data structure Othello

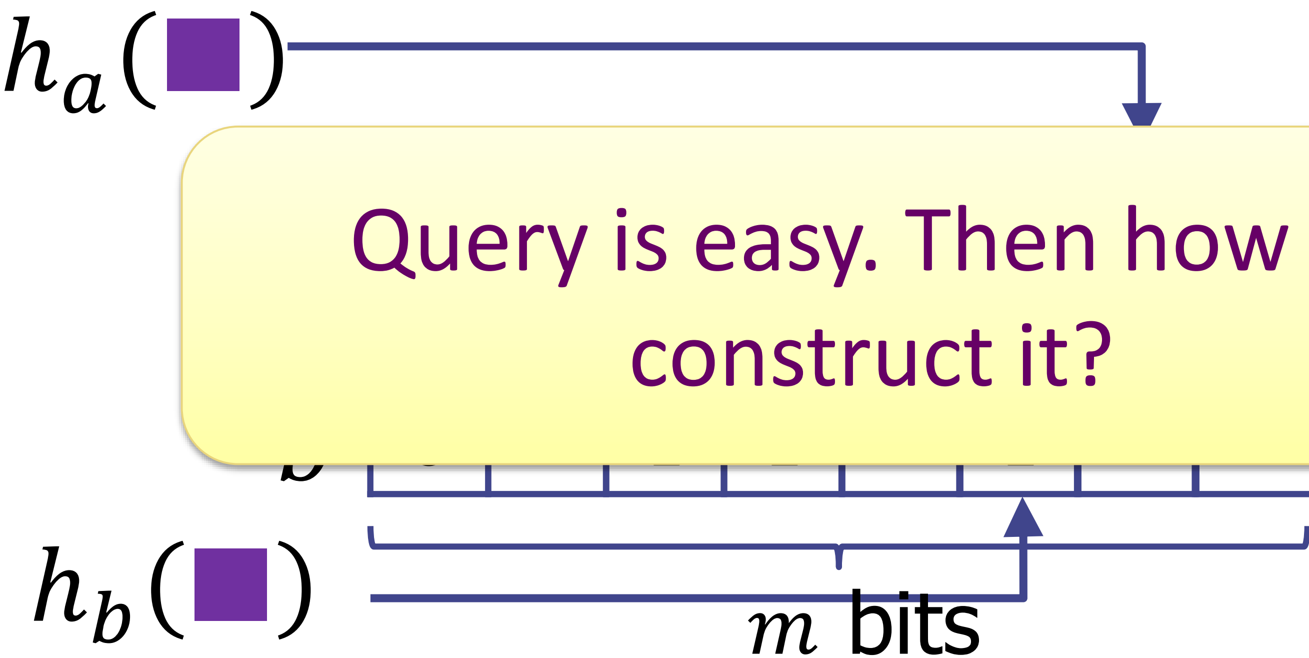
A new data structure Othello

- Classifies names to two sets X and Y
  - Based on MWHC perfect hashing, which is static

- Query result
  - $\tau(k) = 0 \Leftrightarrow k \in X$
  - $\tau(k) = 1 \Leftrightarrow k \in Y$

Othello Query Structure

- Two bitmaps a, b with size m (m in $(1.42n, 2.86n)$)

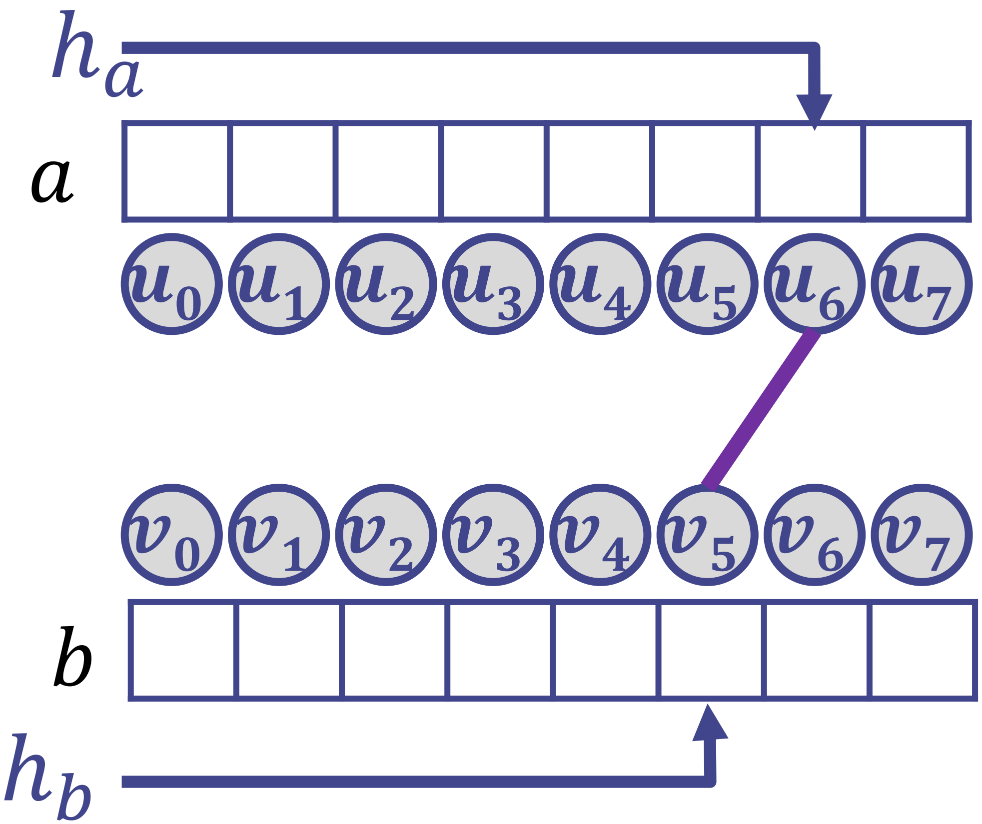


Query is easy. Then how to construct it?

■ is in set Y

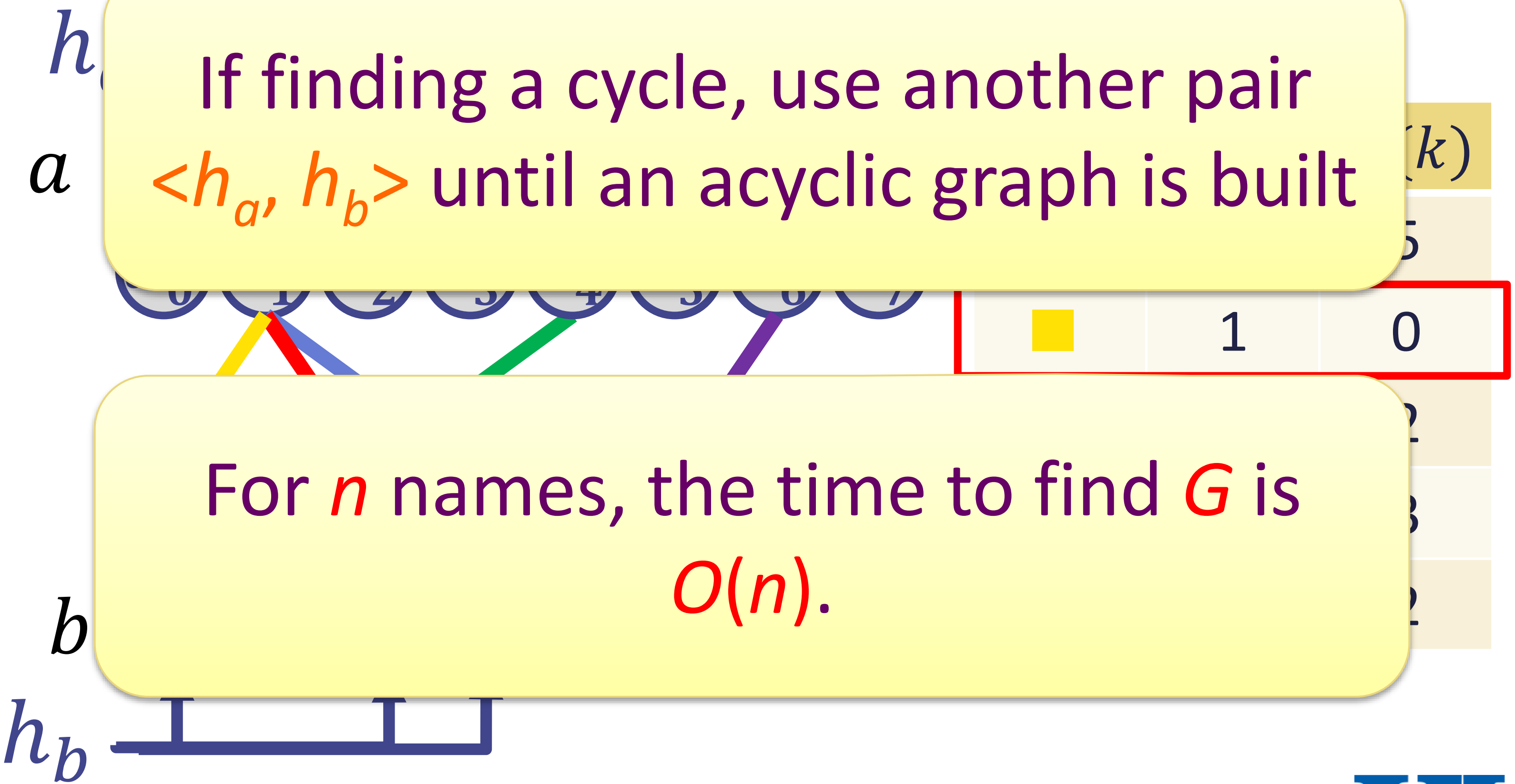
Othello Control Structure: Construct

- G: acyclic bipartite graph



k	$h_a(k)$	$h_b(k)$
■	6	5

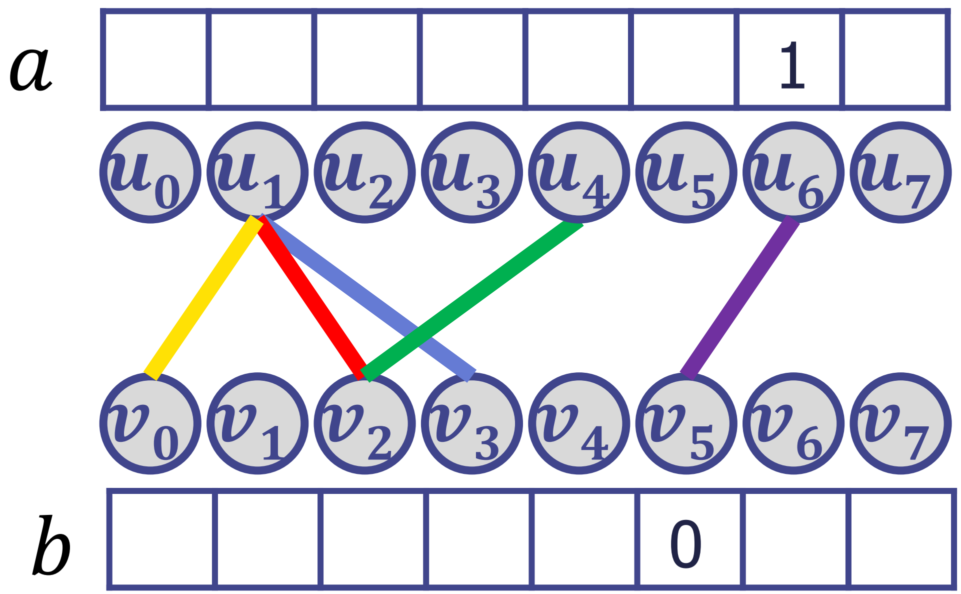
Othello Construct



If finding a cycle, use another pair <h_a, h_b> until an acyclic graph is built

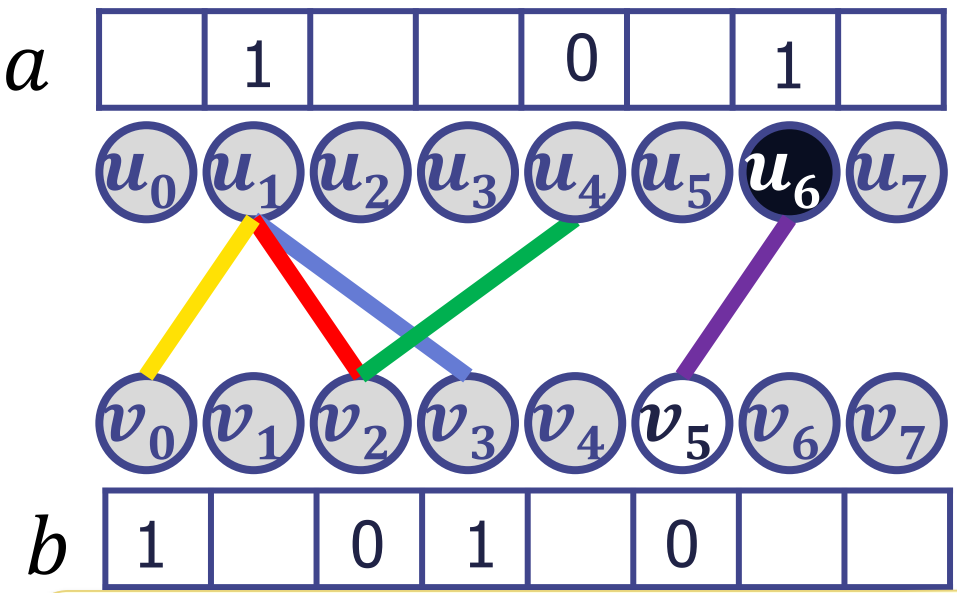
For n names, the time to find G is $O(n)$.

Compute Bitmap



k	$h_a(k)$	$h_b(k)$	set
	6	5	Y
	1	0	
	1	2	
	1	3	
	4	2	

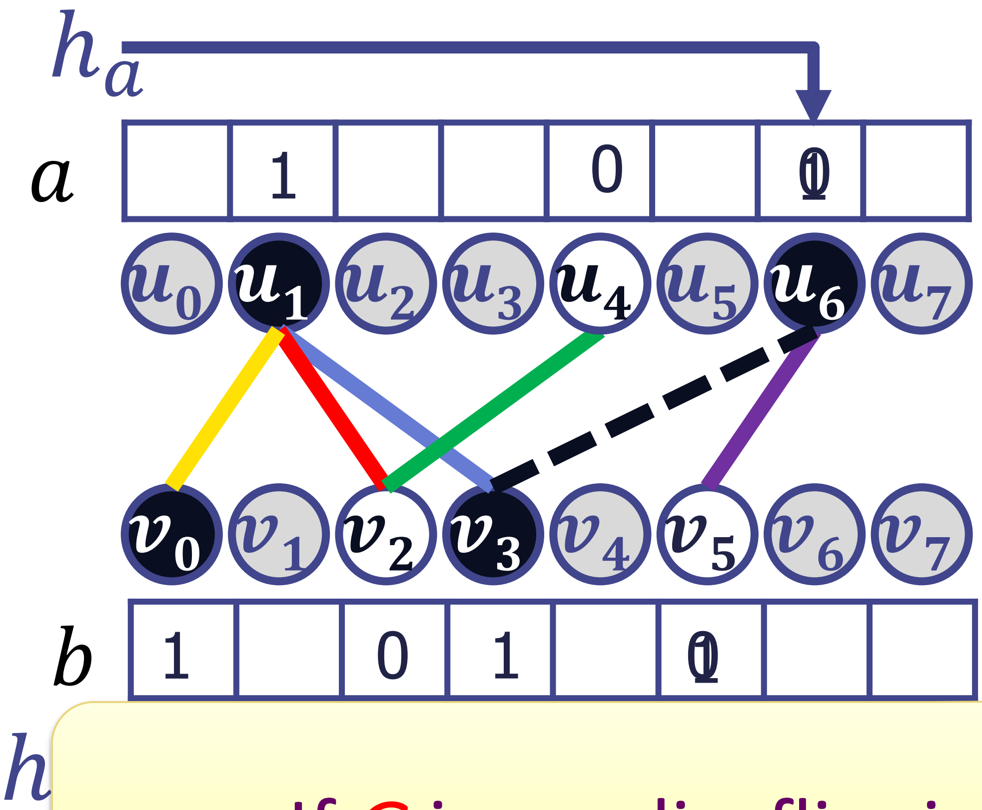
Compute Bitmap



k	$h_a(k)$	$h_b(k)$	set
	6	5	Y
	1	0	X
	1	2	Y
	1	3	X
	4	2	X

If *G* is acyclic, easy to find a coloring plan

Name Addition – color flip

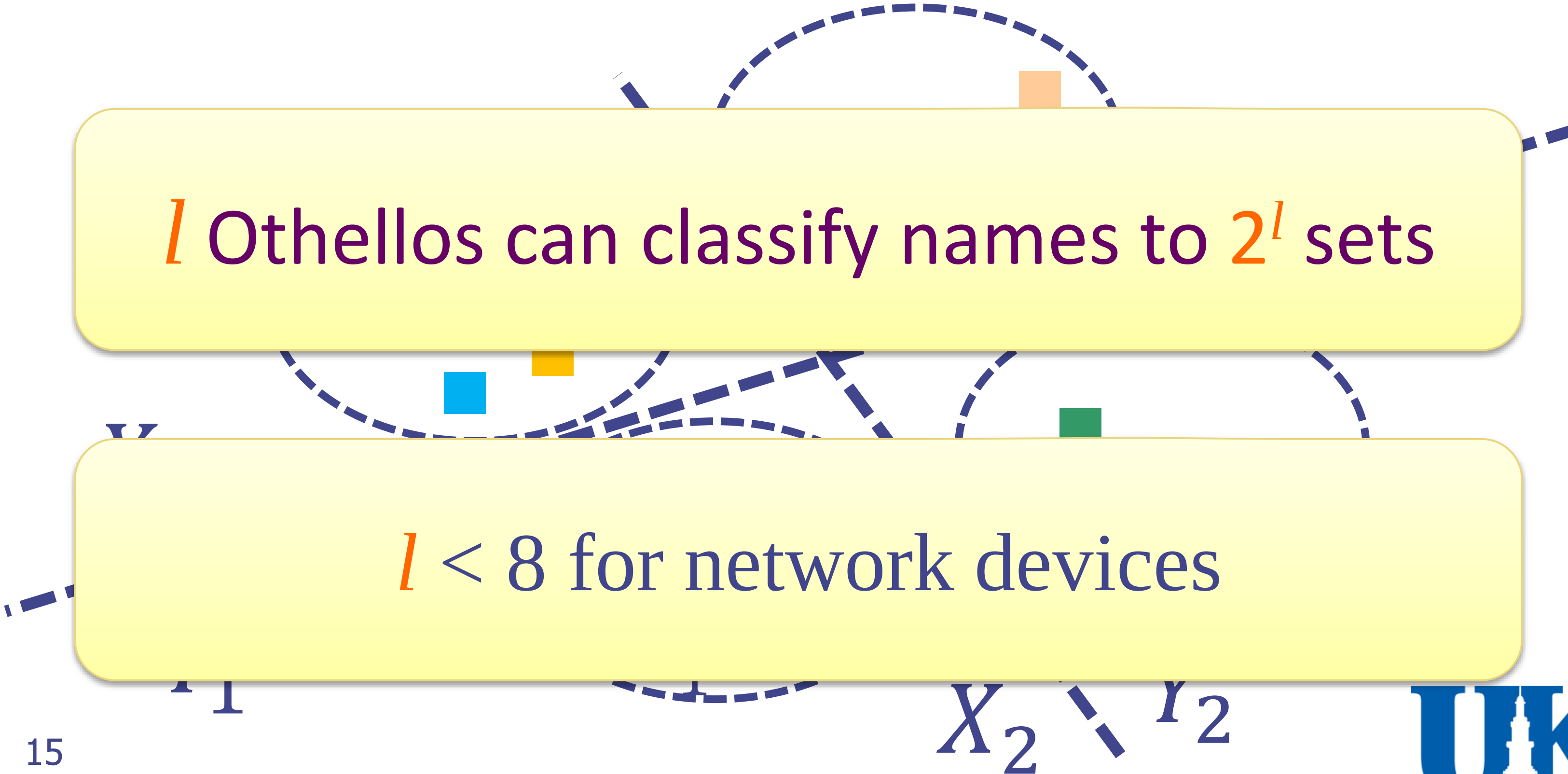


k	$h_a(k)$	$h_b(k)$	set
	6	5	Y
	1	0	X
	1	2	Y
	1	3	X
	4	2	X
	6	3	Y

If G is acyclic, flipping is trivial

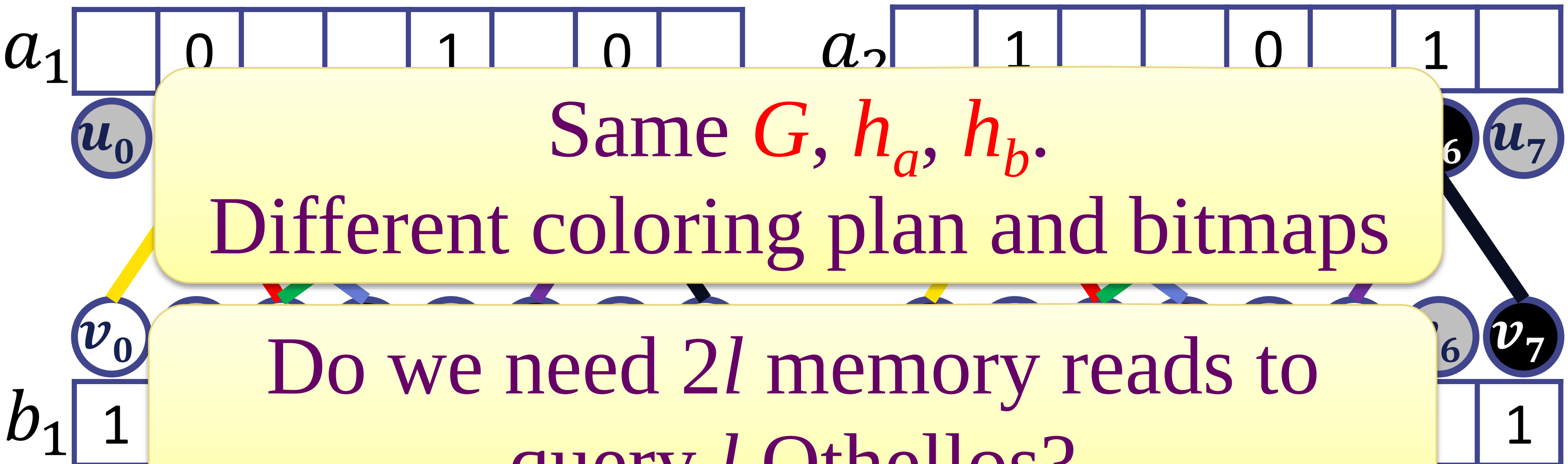
Concise functionality

- Classifies names into 2^l sets: $Z_0, Z_1, \cdots, Z_{2^l-1}$



l Othellos can classify names to 2^l sets

$l < 8$ for network devices

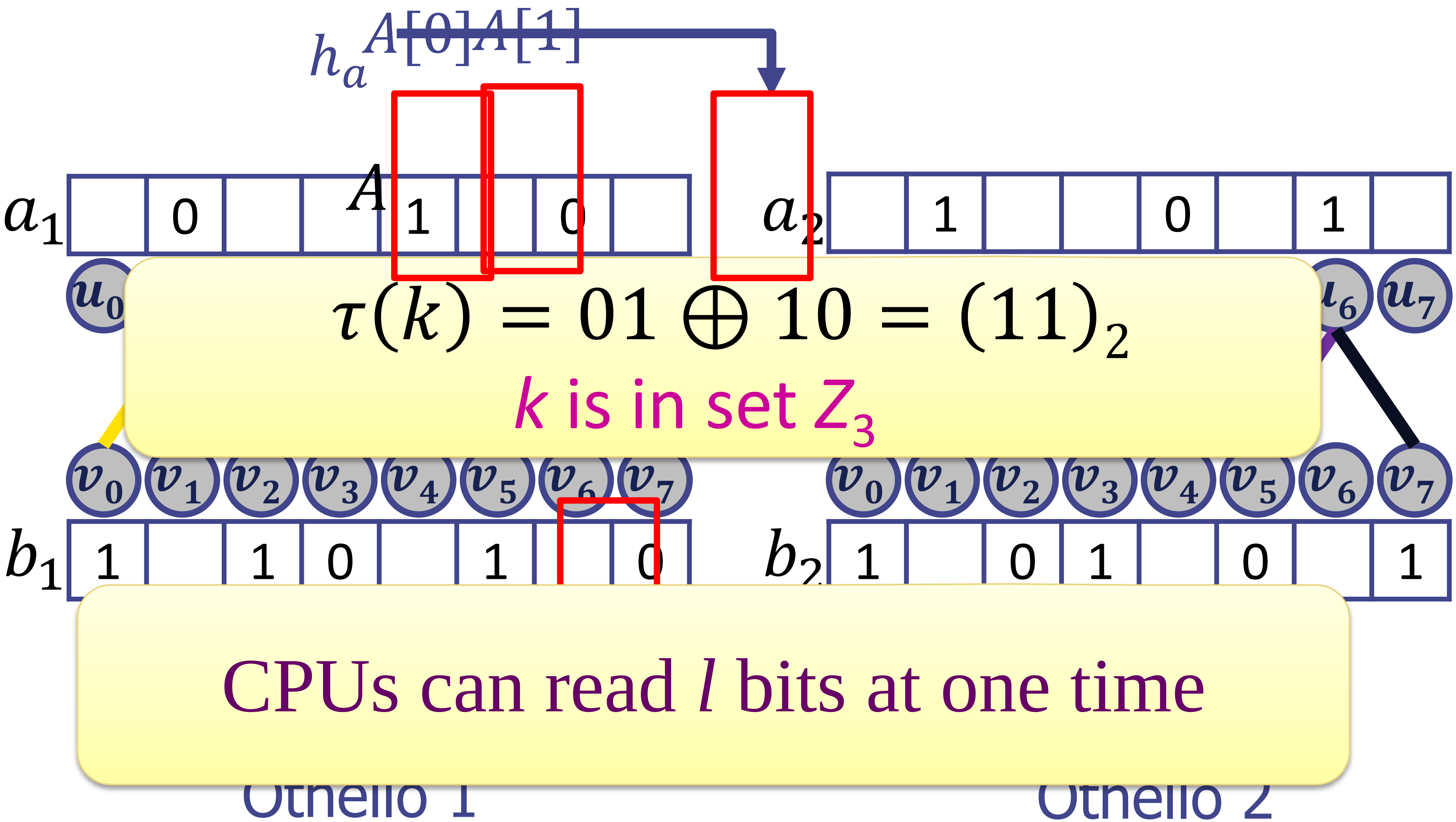


Same G, h_a, h_b.

Different coloring plan and bitmaps

Do we need $2l$ memory reads to query l Othellos?

Othello 1 Same $X \cup Y$ Othello 2



$$\tau(k) = 01 \oplus 10 = (11)_2$$

k is in set Z_3

CPUs can read *l* bits at one time

Implementation of three prototypes

- 1. Memory mode
  - Query and control structures running on different threads.
- 2. CLICK modular router
- 3. Intel Data Plane Development Kit (DPDK)

Comparison: best solutions in the literature

- Buffalo

in CoNEXT'09

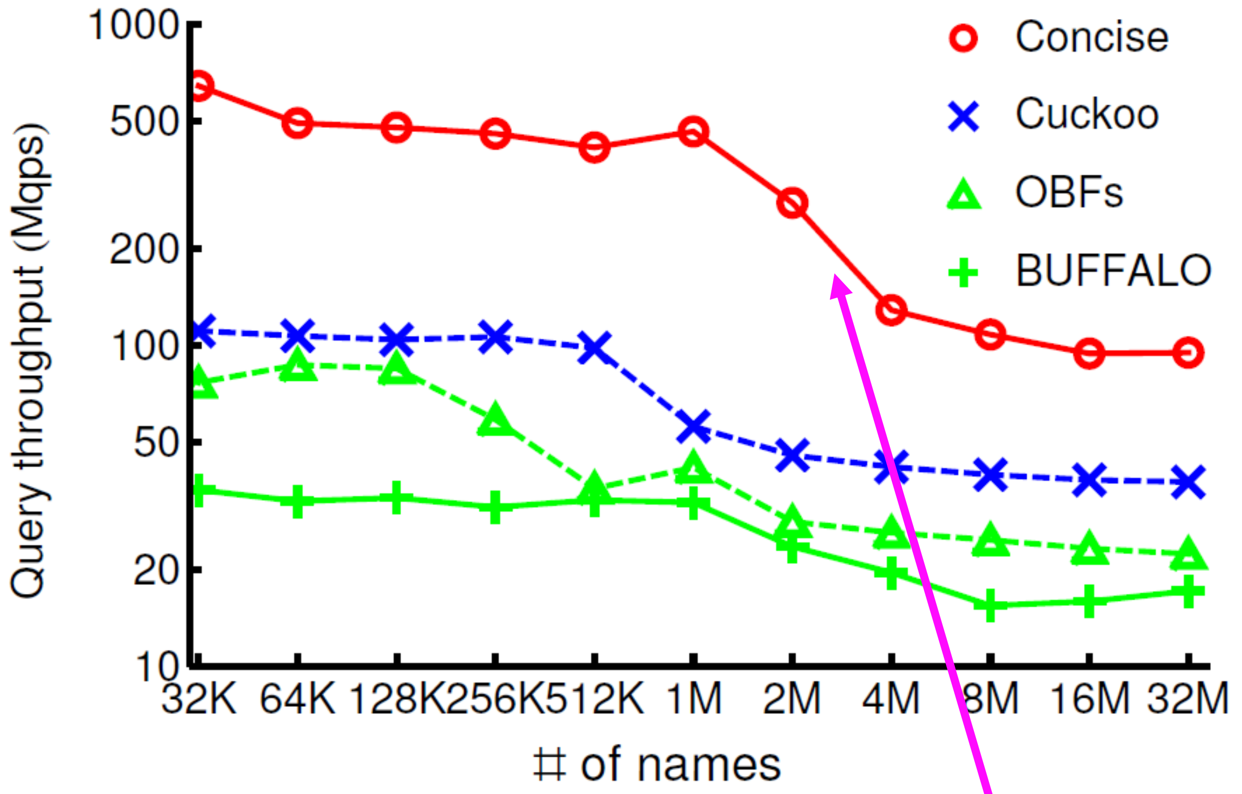
- Cuckoo hashing

in CoNEXT'13 and SIGCOMM'15

Comparison: Memory size

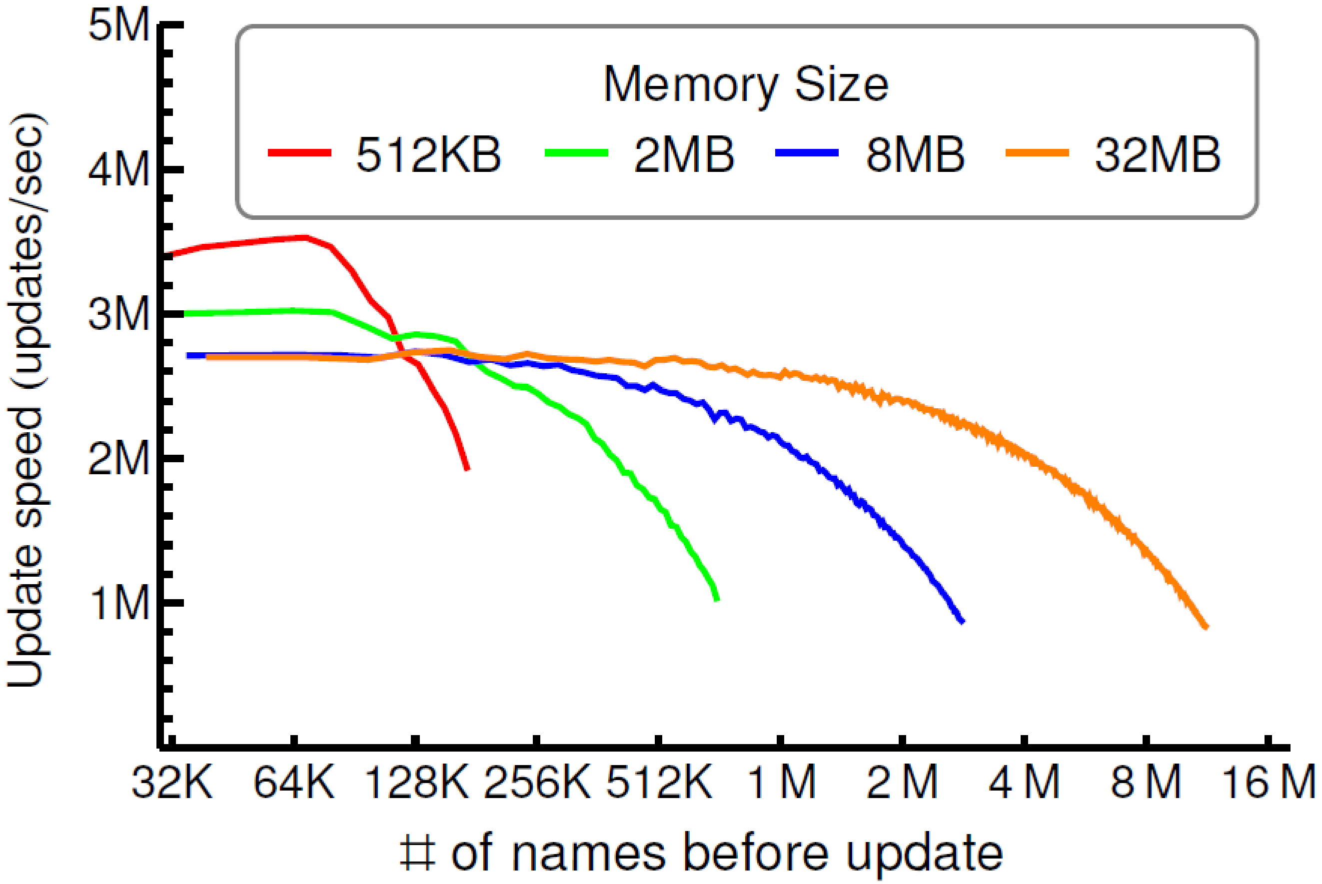
FIB Example			Memory Size		
Name Type	# Names	# Actions	Concise	Cuckoo	Buffalo
MAC (48 bits)	$7*10^5$	16	1M	5.62M	2.64M
MAC (48 bits)	$5*10^6$	256	16M	40.15M	27.70M
MAC (48 bits)	$3*10^7$	256	128M	321.23M	166.23M
IPv4 (32 bits)	$1*10^6$	16	2M	4.27M	3.77M
IPv6 (128 bits)	$2*10^6$	256	8M	34.13M	11.08M
OpenFlow (356 bits)	$3*10^5$	256	1M	14.46M	1.67M
OpenFlow (356 bits)	$1.4*10^6$	65536	8M	67.46M	18.21M
File name (varied)	359194	16	512K	19.32M	1.35M

Query speed



2x to 4x speed advantage

Update



Each update is a network-wide update

More possible applications of Concise

- Essentially a key-value mapping
- 1. Memory cache
- 2. Support query to distributed content storage
- 3. Sparse vector data processing

Thank You

Questions?