

Denormalization

Big Data Systems

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Motivation (for this course)

- The basics of wide column data modeling

Functional dependency

- A constraint between two sets of attributes

$X \rightarrow Y$

For example

- $\{\text{country}\} \rightarrow \{\text{continent}\}$
if we know the country is France, we know the continent is Europe
- $\{\text{user_id}\} \rightarrow \{\text{user_name}\}$
if we know the user id is 123 we know it is "Rubi"

Relational DB & Normalization

- “requires” the data to be normalized in order to
 - Reduce data redundancy
 - Improve data integrity

Relational DB & Normalization

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 - Improve data integrity

A relation R is in 3rd normal form if:

**Whenever there is a nontrivial dependency $A_1, A_2, \dots, A_n \rightarrow B$ for R, then $\{A_1, A_2, \dots, A_n\}$ a super key for R,
or B is part of a key**

(See “Database Systems” course for more info)

Normalization - Example

users-ver1

<u>user id</u>	fname	lname	city	country
101	Rubi	Boim	Tel Aviv	Israel
102	Tova	Milo	Tel Aviv	Israel
103	Lebron	James	Los Angeles	USA

What are the functional dependencies?

Normalization - Example

users-ver1

<u>user_id</u>	fname	lname	city	country
101	Rubi	Boim	Tel Aviv	Israel
102	Tova	Milo	Tel Aviv	Israel
103	Lebron	James	Los Angeles	USA

What are the functional dependencies?

{user_id} → {fname, lname, city, country}
user_id is a key 👍

Normalization - Example

users-ver1

<u>user id</u>	fname	lname	city	country
101	Rubi	Boim	Tel Aviv	Israel
102	Tova	Milo	Tel Aviv	Israel
103	Lebron	James	Los Angeles	USA

What are the functional dependencies?

{city} \rightarrow {country}
city is not part of the key ✗

Normalization - Example

users-ver1

<u>user id</u>	fname	lname	city	country
101	Rubi	Boim	Tel Aviv	Israel
102	Tova	Milo	Tel Aviv	Israel
103	Lebron	James	Los Angeles	USA

What are the functional dependencies?

{city} \rightarrow {country}
city is not part of the key ✖

Not normalized

Normalization - Example

users-ver1

<u>user_id</u>	fname	lname	city	country
101	Rubi	Boim	Tel Aviv	Israel
102	Tova	Milo	Tel Aviv	Israel
103	Lebron	James	Los Angeles	USA

users-ver2

<u>user_id</u>	fname	lname	city
101	Rubi	Boim	Tel Aviv
102	Tova	Milo	Tel Aviv
103	Lebron	James	Los Angeles

cities

<u>city</u>	country
Tel Aviv	Israel
Los Angeles	USA



Normalization - Example

users-ver1

<u>user_id</u>	fname	lname	city	country
101	Rubi	Boim	Tel Aviv	Israel
102	Tova	Milo	Tel Aviv	Israel
103	Lebron	James	Los Angeles	USA

What is the difference?
Data integrity? Storage?

users-ver2

<u>user_id</u>	fname	lname	city
101	Rubi	Boim	Tel Aviv
102	Tova	Milo	Tel Aviv
103	Lebron	James	Los Angeles

cities

<u>city</u>	country
Tel Aviv	Israel
Los Angeles	USA

Normalized DB

- Data integrity ✓
- Reduced Storage ✓
- JOINS are used to retrieve data

```
SELECT users.*, cities.country  
FROM users, cities  
WHERE users.city = cities.city
```

users				cities	
<u>user_id</u>	fname	lname	city	<u>city</u>	country
101	Rubi	Boim	Tel Aviv	Tel Aviv	Israel
102	Tova	Milo	Tel Aviv		
103	Lebron	James	Los Angeles	Los Angeles	USA

Normalized DB

- Data integrity ✓ **do not scale**
- Reduced Storage ✓ **cheap today**
- **JOINS** are used to retrieve data **do not scale**

```
SELECT users.*, cities.country  
FROM users, cities  
WHERE users.city = cities.city
```

users				cities	
<u>user_id</u>	fname	lname	city	<u>city</u>	country
101	Rubi	Boim	Tel Aviv	Tel Aviv	Israel
102	Tova	Milo	Tel Aviv	Los Angeles	USA
103	Lebron	James	Los Angeles		

Denormalization

- No 3NF
- **Improve reads / writes performance dramatically**
 - At the expense of data integrity and storage
 - Requires more writes
- Also applied on relational DBs
- “Workaround” when joins are unavailable (wide columns DBs)

Example (continue)

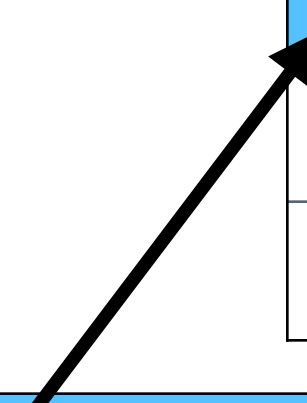
```
SELECT users.*, cities.country
FROM users, cities
WHERE users.city = cities.city
```

users

<u>user id</u>	fname	lname	city
101	Rubi	Boim	Tel Aviv
102	Tova	Milo	Tel Aviv
103	Lebron	James	Los Angeles

cities

<u>city</u>	country
Tel Aviv	Israel
Los Angeles	USA



```
SELECT * FROM users-deno
```

users-deno

<u>user id</u>	fname	lname	city	country
101	Rubi	Boim	Tel Aviv	Israel
102	Tova	Milo	Tel Aviv	Israel
103	Lebron	James	Los Angeles	USA

Example (continue)

```
SELECT users.*, cities.country
FROM users, cities
WHERE users.city = cities.city
```

users

<u>user id</u>	fname	lname	city
101	Rubi	Boim	Tel Aviv
102	Tova	Milo	Tel Aviv
103	Lebron	James	Los Angeles

cities

<u>city</u>	country
Tel Aviv	Israel
Los Angeles	USA

```
SELECT * FROM users-deno
```

users-deno

<u>user id</u>	fname	lname	city	country
101	Rubi	Boim	Tel Aviv	Israel
102	Tova	Milo	Tel Aviv	Israel
103	Lebron	James	Los Angeles	USA

If you have 10k queries per second, which will be faster?

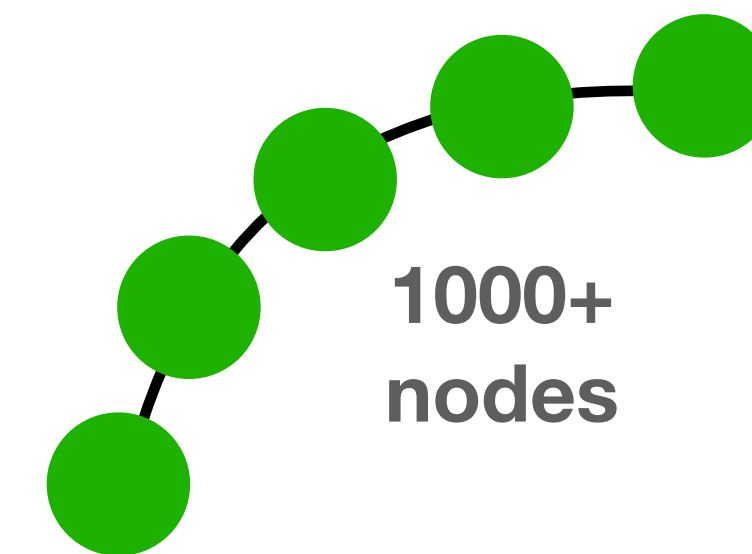
Moving to Cassandra

<u>user id</u>	fname	lname	city	country
101	Rubi	Boim	Tel Aviv	Israel
102	Tova	Milo	Tel Aviv	Israel
103	Lebron	James	Los Angeles	USA



What about this query

```
SELECT * FROM users  
WHERE country = "Israel"
```



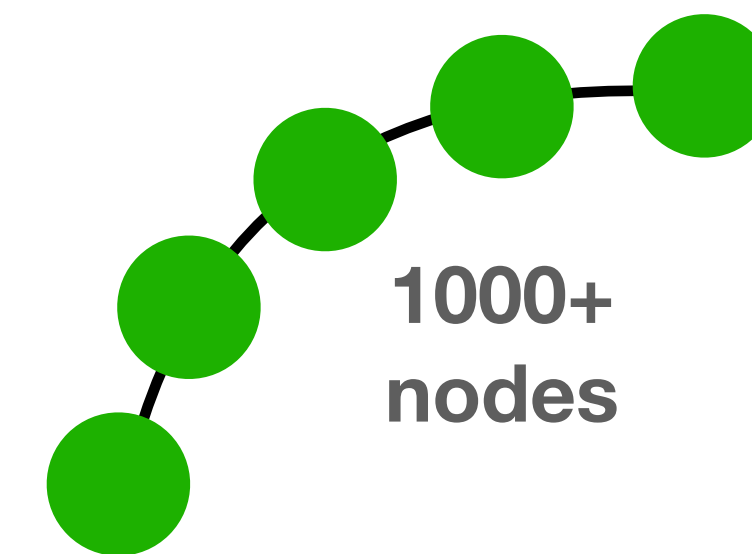
Moving to Cassandra

<u>user id</u>	fname	lname	city	country
101	Rubi	Boim	Tel Aviv	Israel
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103	Lebron	James	Los Angeles	USA



What about this query

```
SELECT * FROM users  
WHERE country = "Israel"
```



Error... how can we solve this?

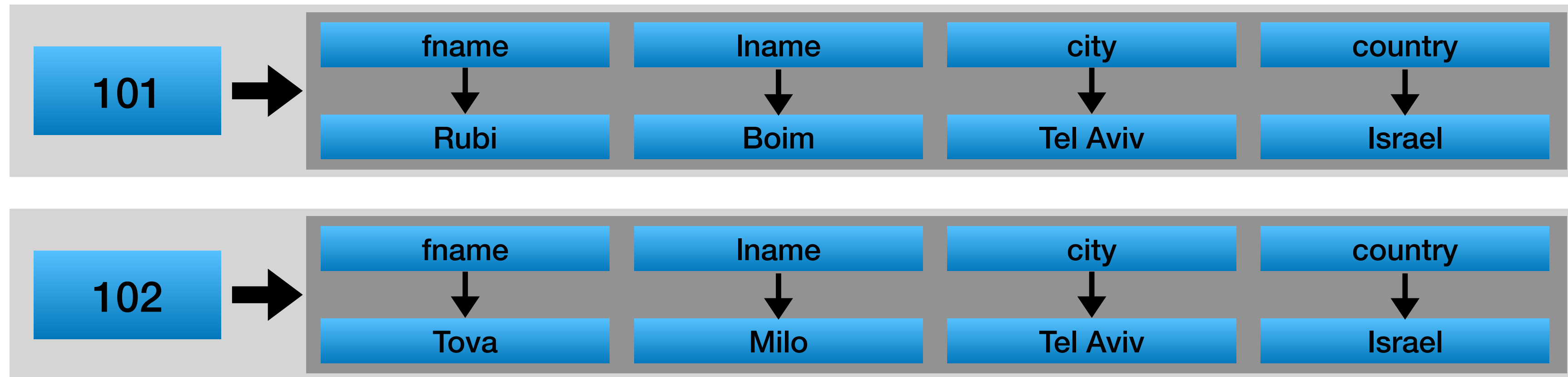
Denormalization by 2 tables

```
CREATE TABLE users_by_id (  
  user_id      BIGINT,  
  fname       TEXT,  
  lname       TEXT,  
  city        TEXT,  
  country     TEXT,  
  PRIMARY KEY ((user_id))  
);
```

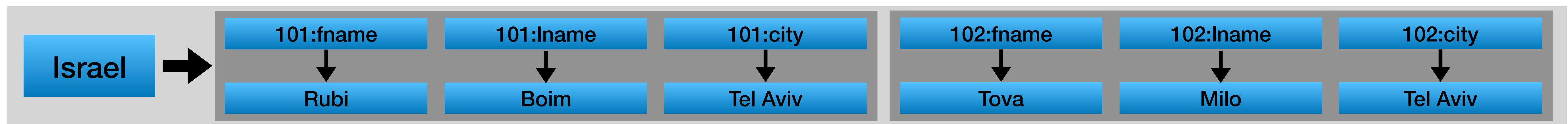
```
CREATE TABLE users_by_country (  
  country     TEXT,  
  user_id     BIGINT,  
  fname       TEXT,  
  lname       TEXT,  
  city        TEXT,  
  PRIMARY KEY ((country), user_id)  
);
```

Denormalization by 2 tables

users_by_id



users_by_country

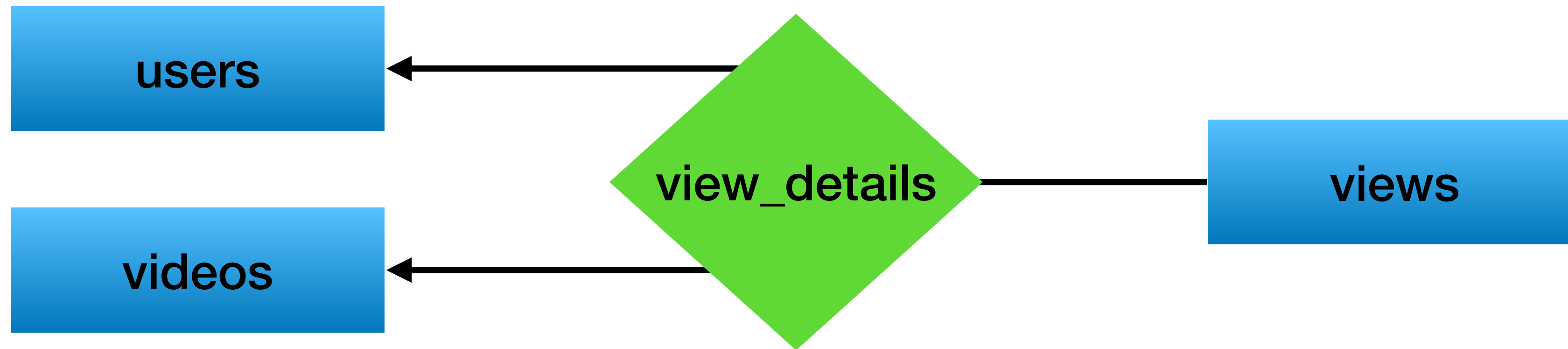


```
SELECT * FROM users_by_country WHERE country = "Israel"
```

Interesting .

- We saw 2 different ways to denormalize:
 - Merging 2 tables into 1 table
 - Splitting 1 table into 2 tables
- Denormalization is **crucial** for “correct” data modeling in Big Data

Example - Relational



users

user_id	name	city	...
101	Rubi Boim	Tel Aviv	
102	Tova Milo	Tel Aviv	
103	Lebron James	Los Angeles	

videos

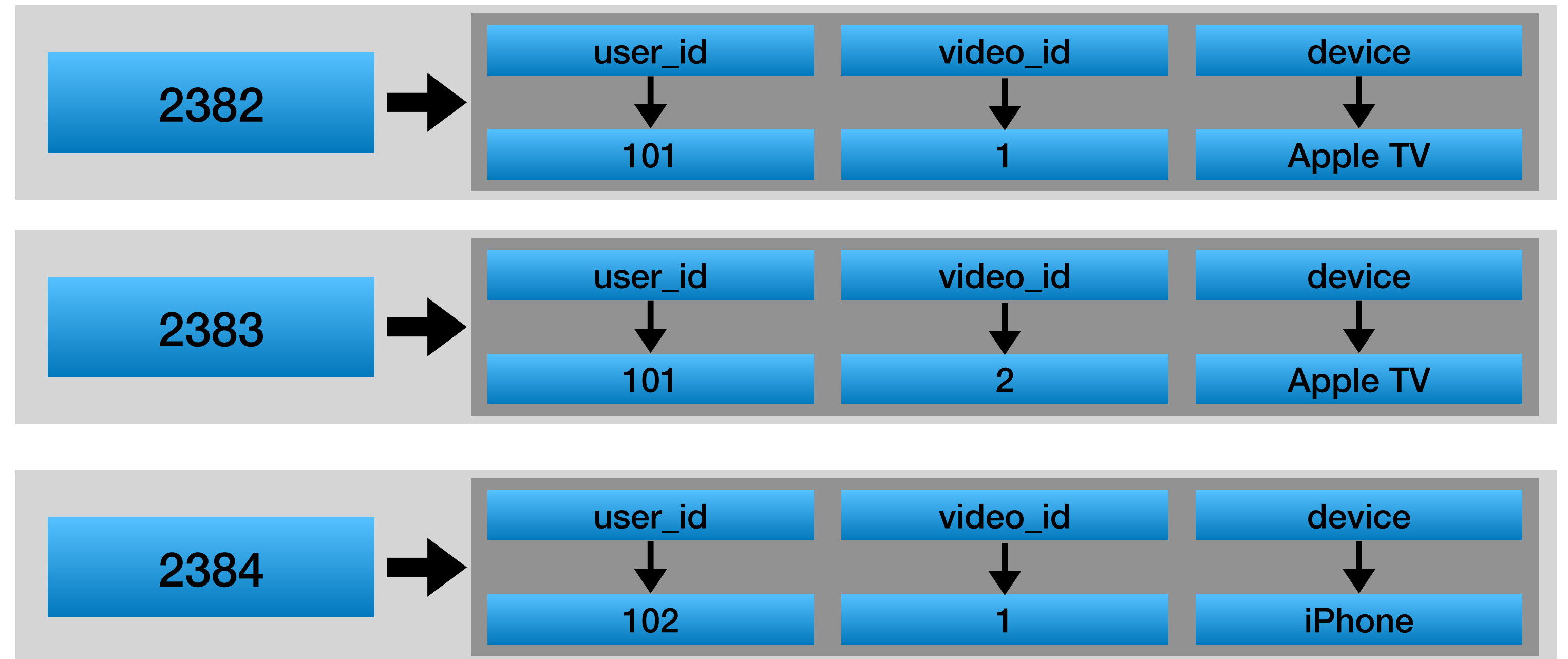
video_id	title	year	...
1	Bad Boys	1995	
2	Top Gun	1986	
3	American Pie	1999	

views

view_id	user_id	video_id	device	...
2382	101	1	Apple TV	
2383	101	2	Apple TV	
2384	102	1	iPhone	

Example - Cassandra

```
CREATE TABLE views (  
  view_id      TIMEUUID,  
  user_id      BIGINT,  
  video_id     BIGINT,  
  device       TEXT,  
  PRIMARY KEY ((view_id))  
);
```

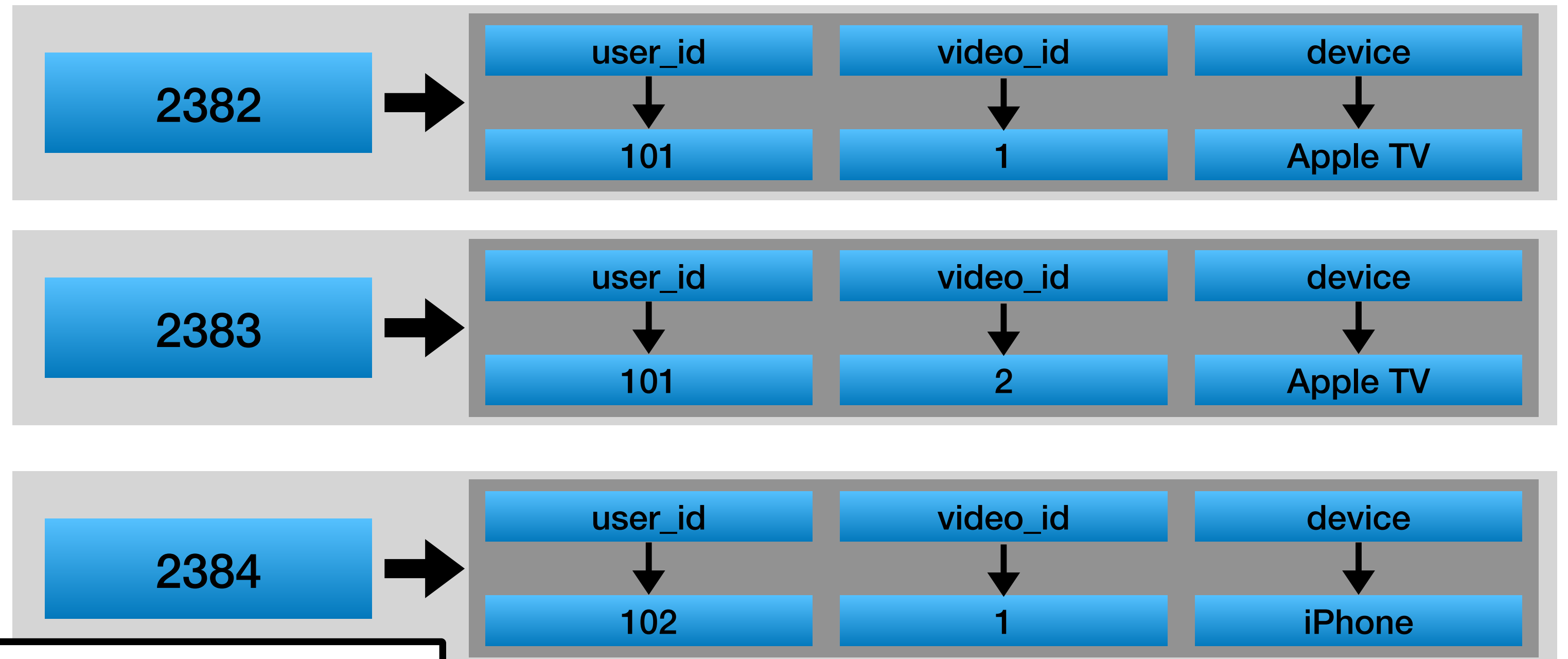


Which queries can we efficiently return?

views				
view_id	user_id	video_id	device	...
2382	101	1	Apple TV	
2383	101	2	Apple TV	
2384	102	1	iPhone	

Example - Cassandra

```
CREATE TABLE views (  
  view_id      TIMEUUID,  
  user_id      BIGINT,  
  video_id     BIGINT,  
  device       TEXT,  
  PRIMARY KEY ((view_id))  
);
```



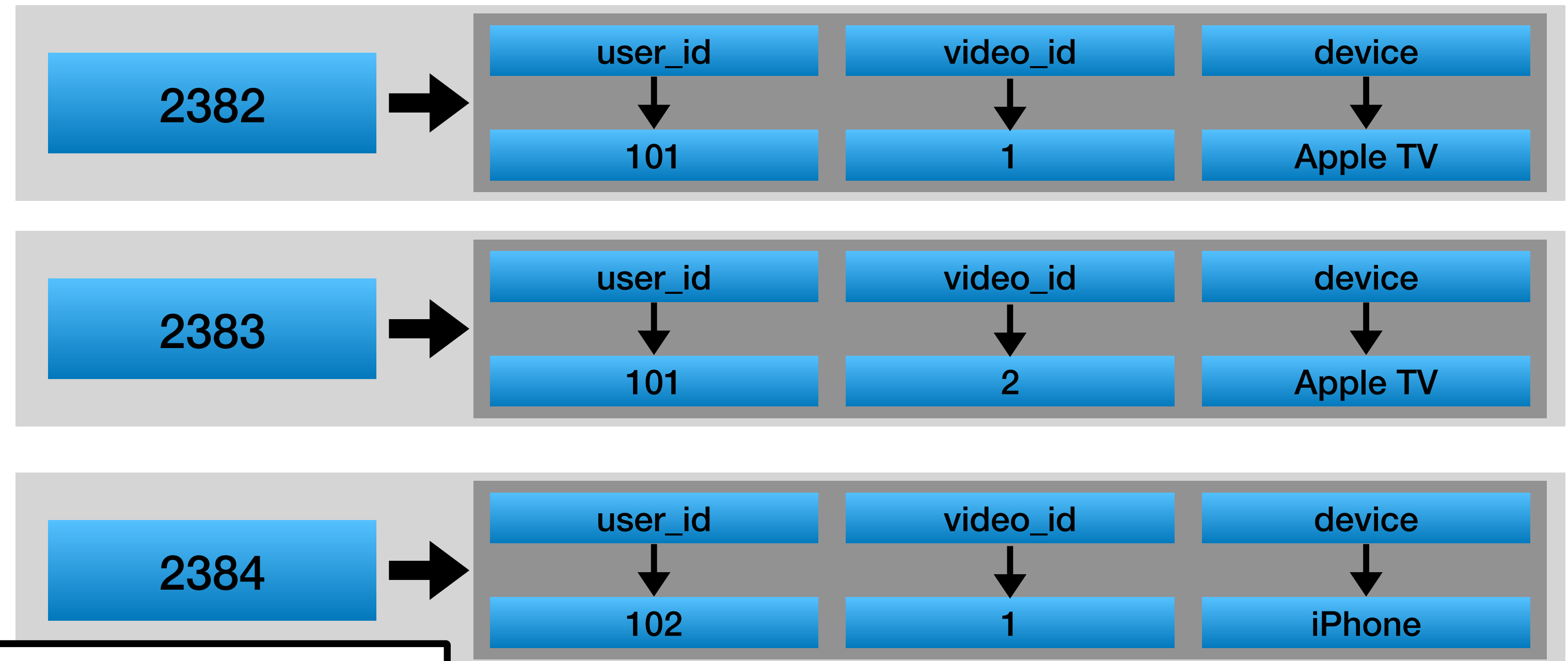
SELECT * FROM views WHERE view_id = ?

Which queries can we efficiently return?

views				
view_id	user_id	video_id	device	...
2382	101	1	Apple TV	
2383	101	2	Apple TV	
2384	102	1	iPhone	

Example - Cassandra

```
CREATE TABLE views (  
  view_id      TIMEUUID,  
  user_id     BIGINT,  
  video_id    BIGINT,  
  device      TEXT,  
  PRIMARY KEY ((view_id))  
);
```



SELECT * FROM views WHERE view_id = ?

Which queries can we efficiently return?

views

view_id	user_id	video_id	device	...
2382	101	1	Apple TV	
2383	101	2	Apple TV	
2384	102	1	iPhone	

Probably the queries will be by the user/movie
How can we support this?

Denormalization by 2 tables

```
CREATE TABLE views_by_user (  
  user_id      BIGINT,  
  view_id     TIMEUUID,  
  video_id    BIGINT,  
  device      TEXT,  
  PRIMARY KEY ((user_id), view_id)  
) WITH CLUSTERING ORDER BY  
  (view_id DESC);
```

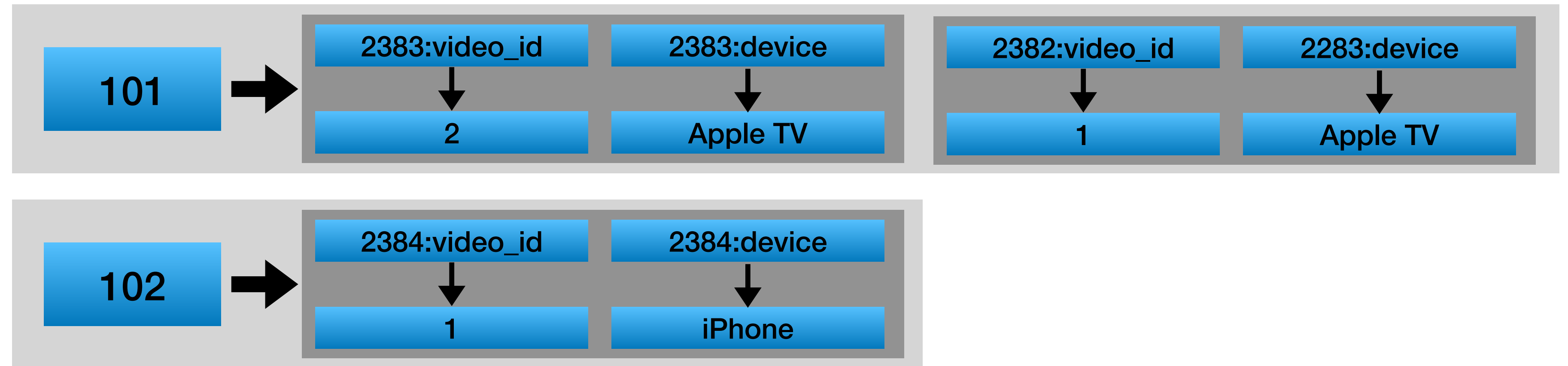
```
CREATE TABLE views_by_video (  
  video_id    BIGINT,  
  view_id     TIMEUUID,  
  user_id    BIGINT,  
  device      TEXT,  
  PRIMARY KEY ((video_id), view_id)  
) WITH CLUSTERING ORDER BY  
  (view_id DESC);
```

Efficient queries:

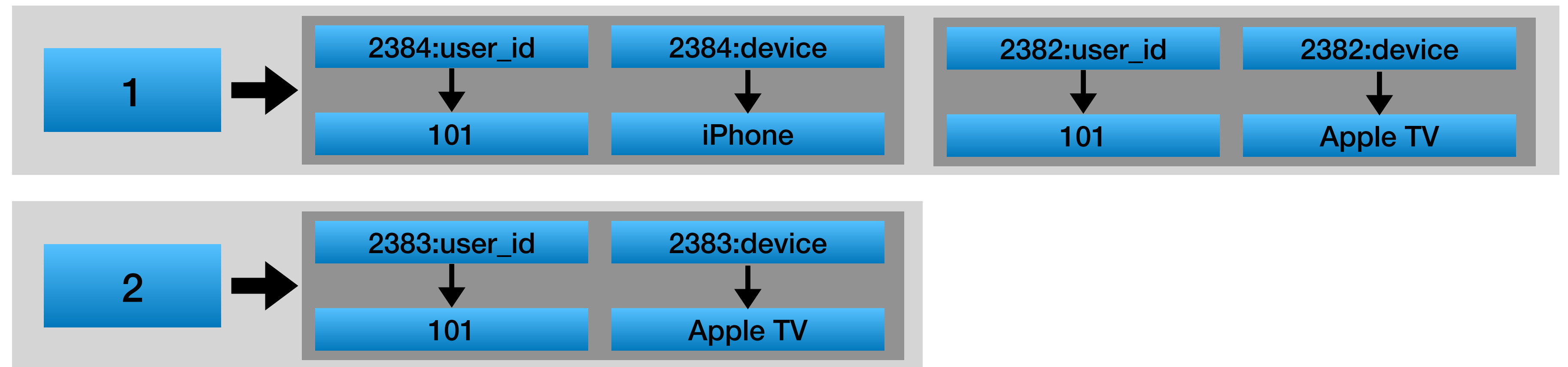
get all recent views of a user
get all recent views of a video

Denormalization by 2 tables

views_by_user



views_by_video



Example continue

How can we return all the views for a specific day?

```
CREATE TABLE views_by_user (  
  user_id      BIGINT,  
  view_id     TIMEUUID,  
  video_id    BIGINT,  
  device      TEXT,  
  PRIMARY KEY ((user_id), view_id)  
) WITH CLUSTERING ORDER BY  
  (view_id DESC);
```

```
CREATE TABLE views_by_video (  
  video_id    BIGINT,  
  view_id     TIMEUUID,  
  user_id    BIGINT,  
  device      TEXT,  
  PRIMARY KEY ((video_id), view_id)  
) WITH CLUSTERING ORDER BY  
  (view_id DESC);
```

Example continue

How can we return all the views for a specific day?

- Create a job (Spark?) that reads all the views from views_by_user and filter the result
- Create a job (Spark?) that reads all the views from views_by_video and filter the result
- Denormalize to another table

What is the difference between the options (time / IO)?

3rd denormalization

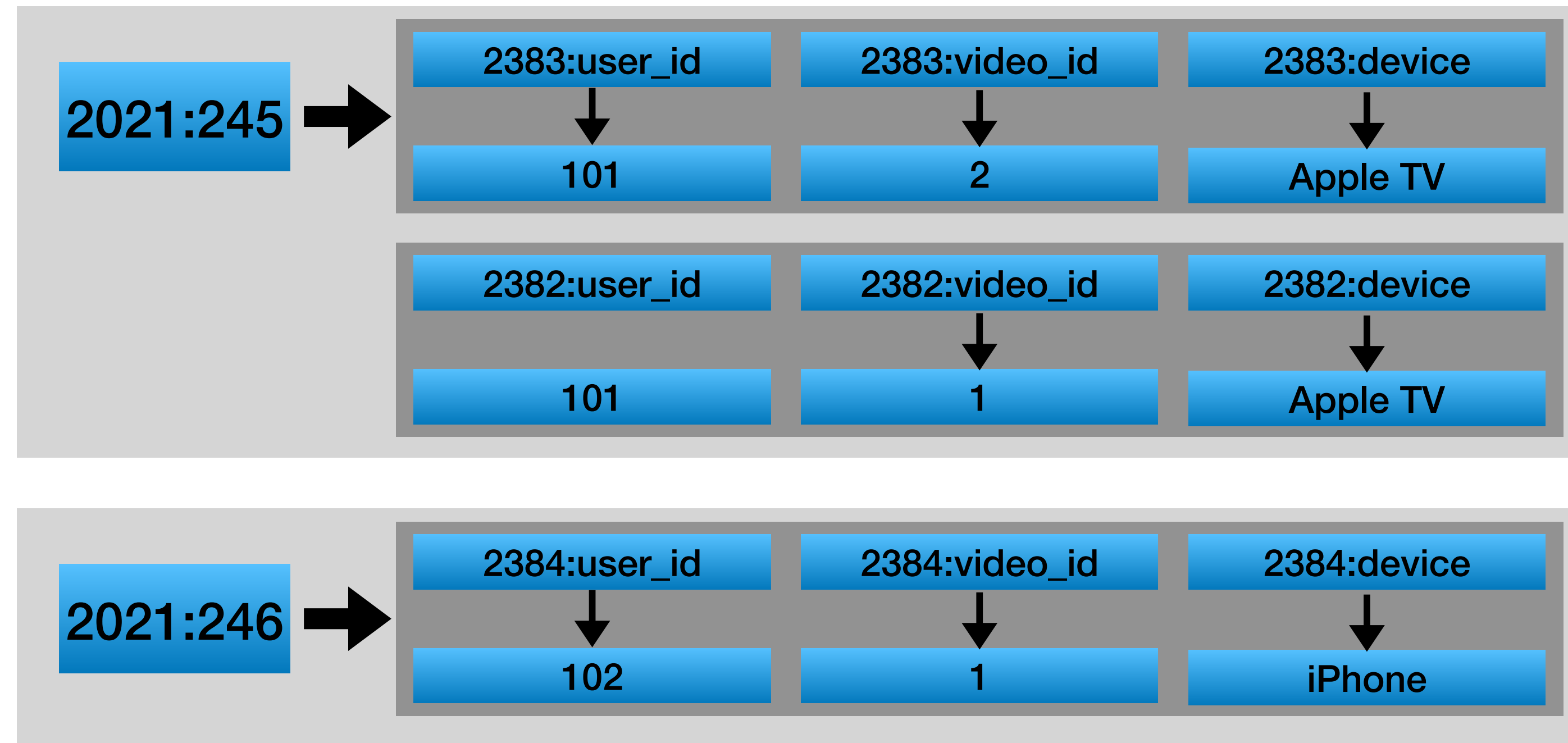
```
CREATE TABLE views_by_user (  
  user_id      BIGINT,  
  view_id     TIMEUUID,  
  video_id    BIGINT,  
  device      TEXT,  
  PRIMARY KEY ((user_id), view_id)  
) WITH CLUSTERING ORDER BY  
  (view_id DESC);
```

```
CREATE TABLE views_by_video (  
  video_id    BIGINT,  
  view_id     TIMEUUID,  
  user_id    BIGINT,  
  device      TEXT,  
  PRIMARY KEY ((video_id), view_id)  
) WITH CLUSTERING ORDER BY  
  (view_id DESC);
```

```
CREATE TABLE views_by_day (  
  year        INT,  
  day         INT,  
  view_id     TIMEUUID,  
  user_id    BIGINT,  
  video_id   BIGINT,  
  device      TEXT,  
  PRIMARY KEY ((year, day), view_id)  
) WITH CLUSTERING ORDER BY  
  (view_id DESC);
```

3rd denormalization

views_by_day



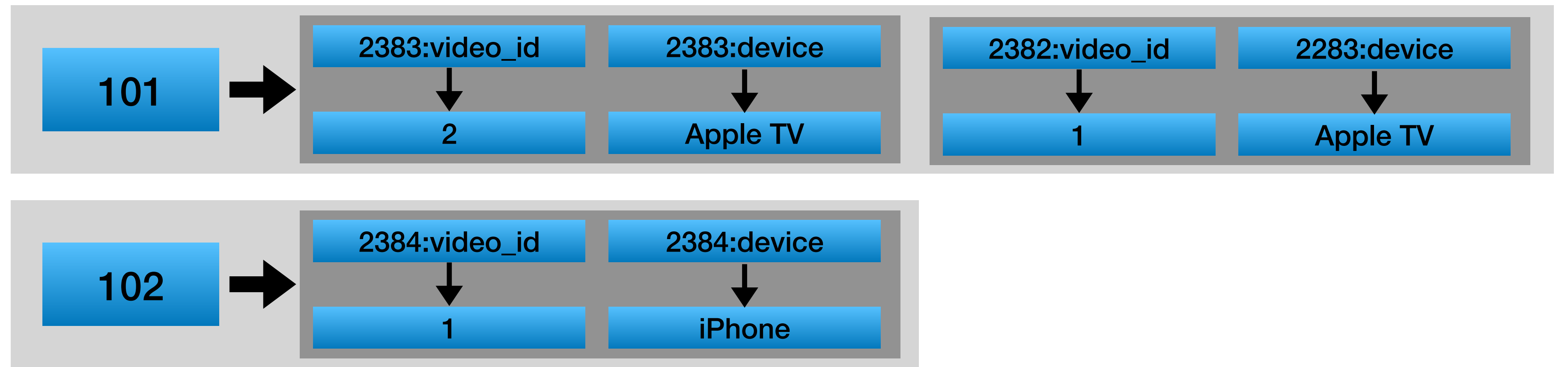
assuming:

- views 2382 and 2383 are on day 245 (2021)
- view 2384 is on day 246 (2021)

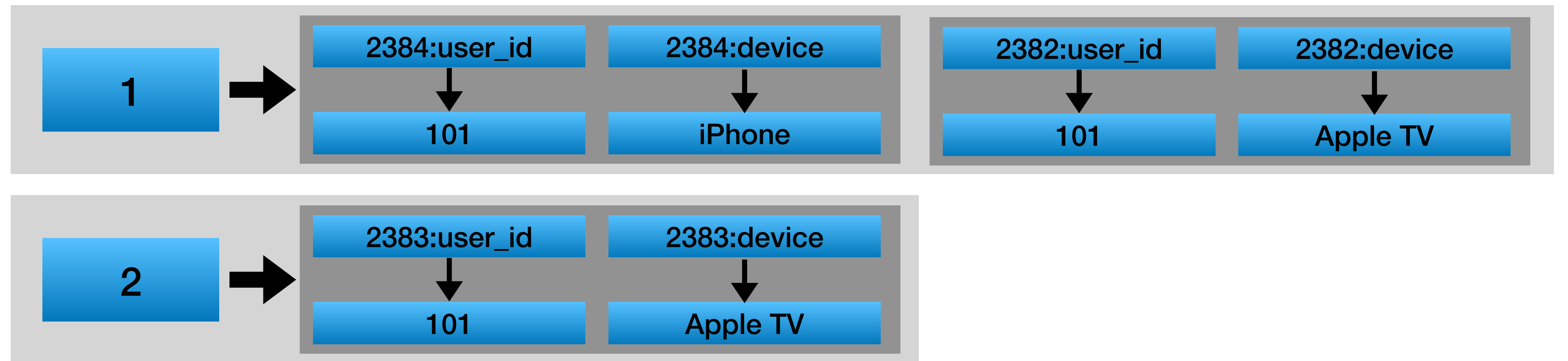
views

view_id	user_id	video_id	device	...
2382	101	1	Apple TV	
2383	101	2	Apple TV	
2384	102	1	iPhone	

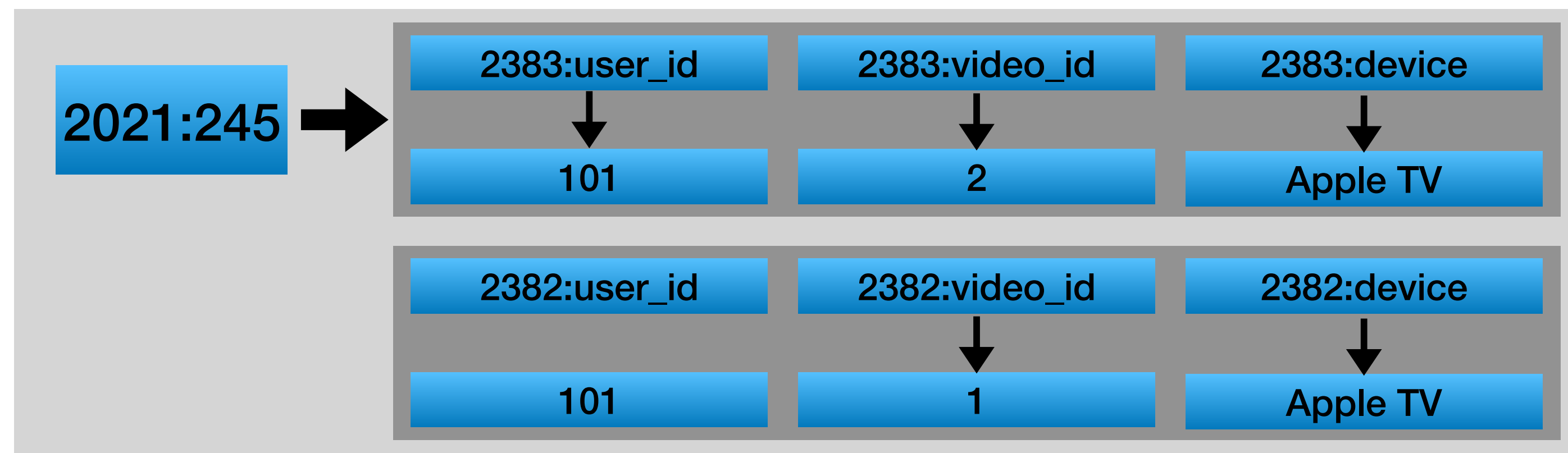
views_by_user



views_by_video



views_by_day



Interesting questions

- What happens if “Game of Thrones” is running?
- What happens if we have +100m views per day?

