

# Wireless!

The forces and strategies that shaped a revolution



## **Lecture 5- Cellular Economics: the million-dollar cell**

# Lecture 5- Classwork

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1. Please summarize in 3-4 sentences the Pre-Lecture reading for **Lecture 5** including some important takeaways from your reading.
2. Why do base stations (cells) cost so much, independent of the number of radios they have installed?
3. Using the CTIA data, what was the cost of a base station (the investment /cell) in 2000? What was the number of users/cell in year 2000?
4. Why do cellular systems start with the largest possible cells?
5. Why does cell-splitting always decrease the cell radius by  $\frac{1}{2}$  as opposed to (say)  $\frac{1}{3}$ ?
6. We have shown that the calculated investment/user in this pre-lecture reading for a 400-channel system with 1000 users/cell is \$1000/user. What would be the investment/user for a monopoly with 800 channels? What would be the investment/user for 4 competing systems with 200 channels each?
7. Why did the fact that the cost of cells is fixed lead to AT&T's argument that a cellular monopoly was in the public interest?
8. Why did AT&T's opponents believe that multiple systems in each location were necessary? What was the FCC's compromise?

# The Million Dollar Cell

Mostly “fixed” costs (not just radios) **Q2**



**Legal fees for local approval\***

**Land and improvements**

**Engineering planning\***

**A building**

**Mast, antennas, cables**

**Radios, combiners**

**Control equipment**

**Maintenance equipment**

**Information systems**

**Connection to electrical power**

**Backup power**

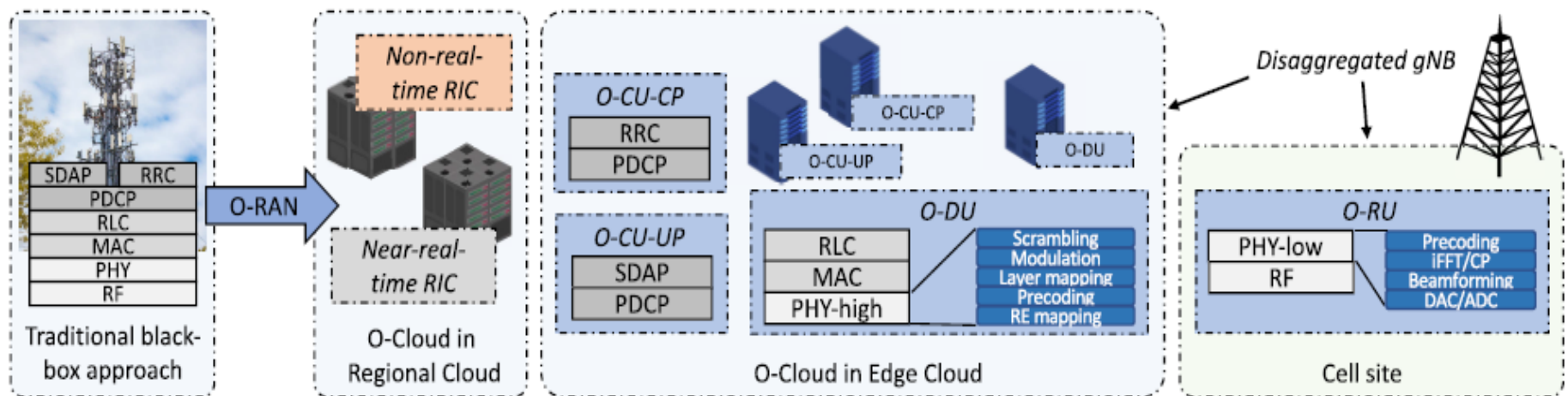
**Connection to central switch**

**\*These “people costs” are significant and are included in the cost of a cell**

# Aside: Beyond 5G and Next G- O-RAN

## ❑ O-RAN: Open Radio Access Networks

- From Traditional Base Station Architecture to Virtualized Cloud-based Architecture
- Virtualized RANs where disaggregated components are connected via open interfaces and optimized by intelligent controllers



# The Million Dollar Cell

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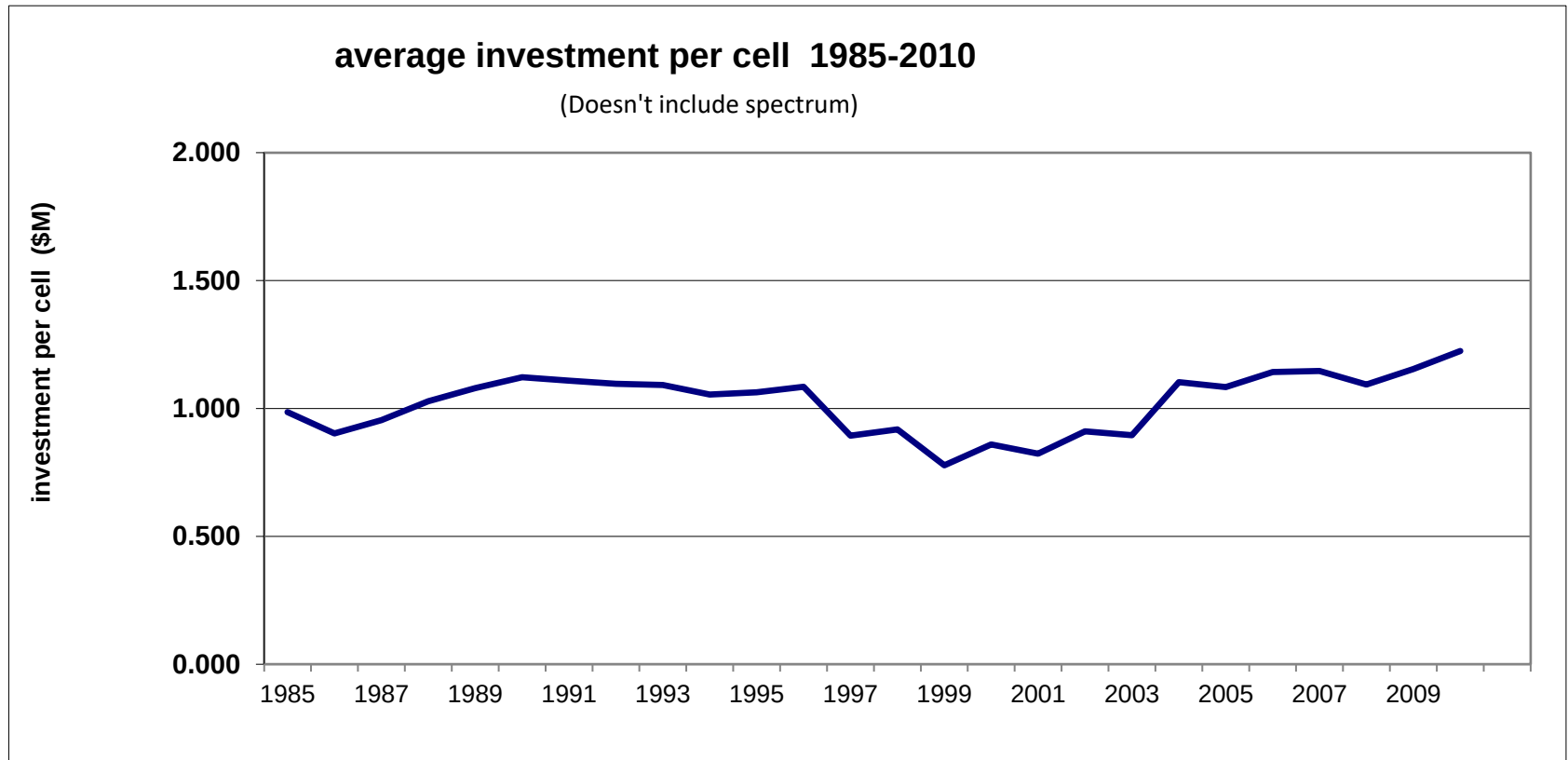
**Backup power**

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# Confirmed with the CTIA data

Q3, Q4

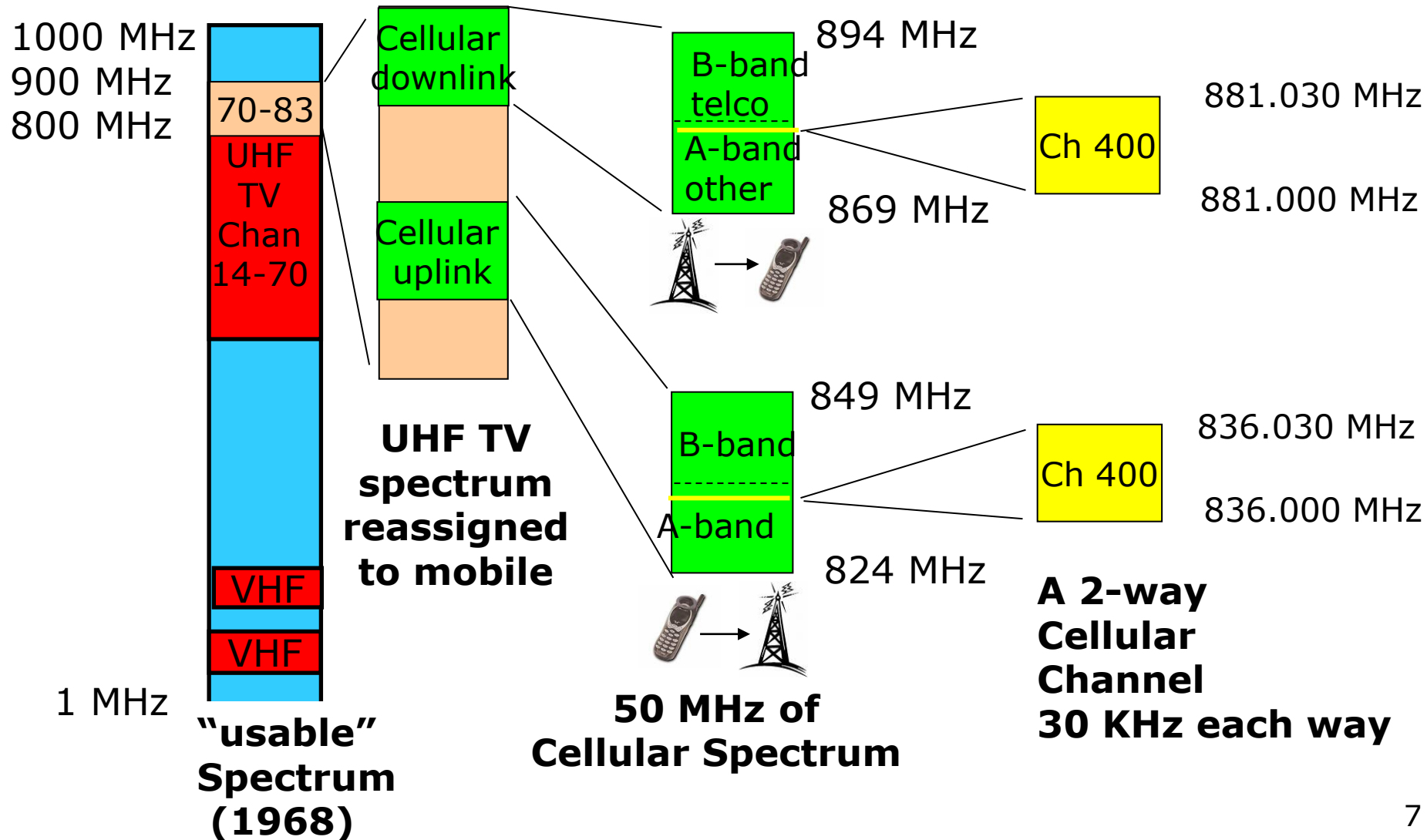


**There are some other investment costs like the central switch, but we can ignore them (compared to the base stations)**

**Why was the cost of a base station starting to increase after 2008?**

# Frequency MHz and spectrum MHz

50 MHz at “900 MHz”, 2 operators/city



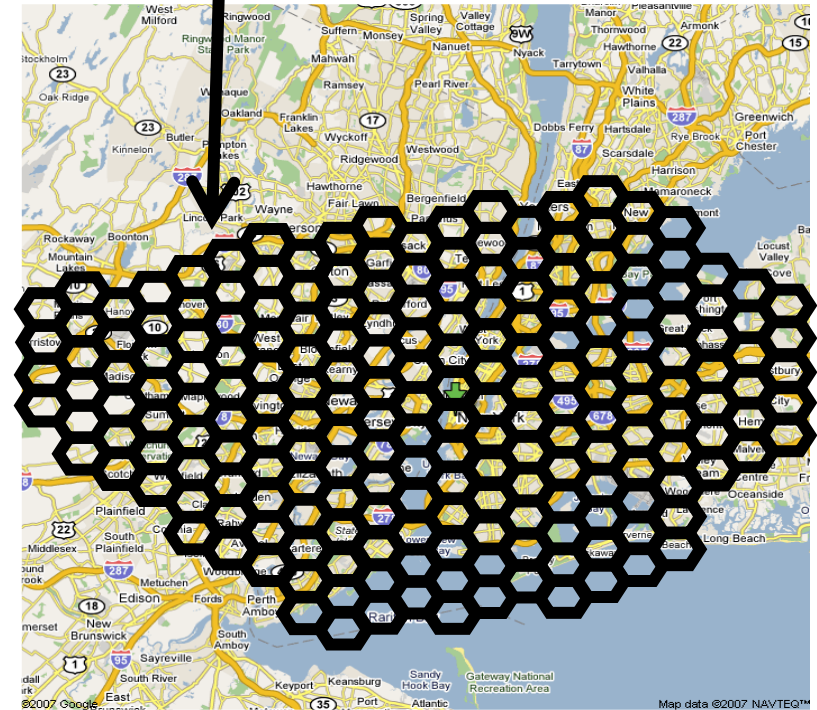
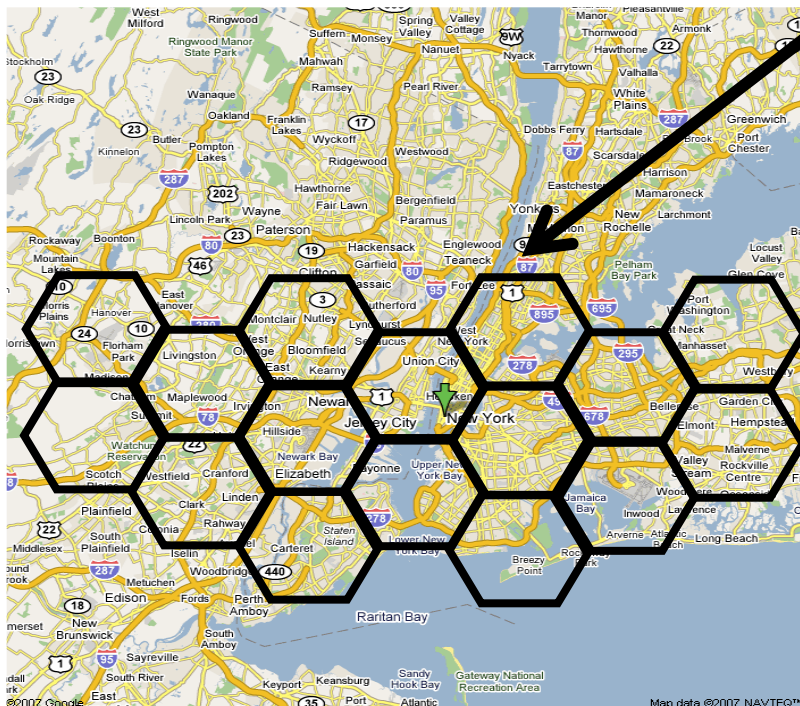
# Baseline Assumptions for Analysis

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- System with 400 channels and 7 cell reuse pattern
  - ~ \$1M per cell
  - ~ 1000 users per cell
  - ~ \$1000 investment per user
- Validated by CTIA data

# Growing the system: We need to start with large cells to limit the investment per user

## How do we get from to

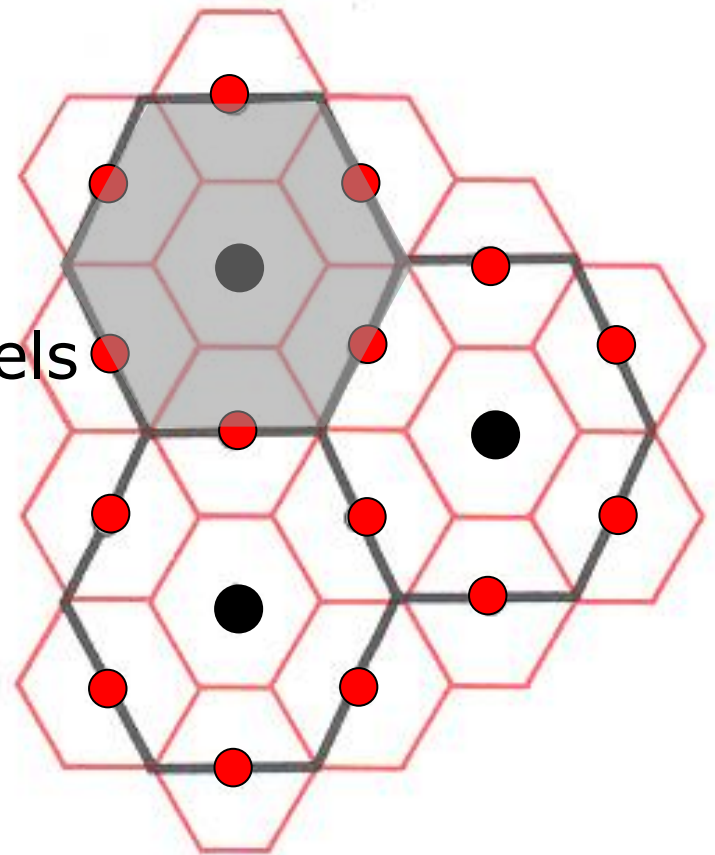


While preserving all the old base stations  
that we paid a million dollars for

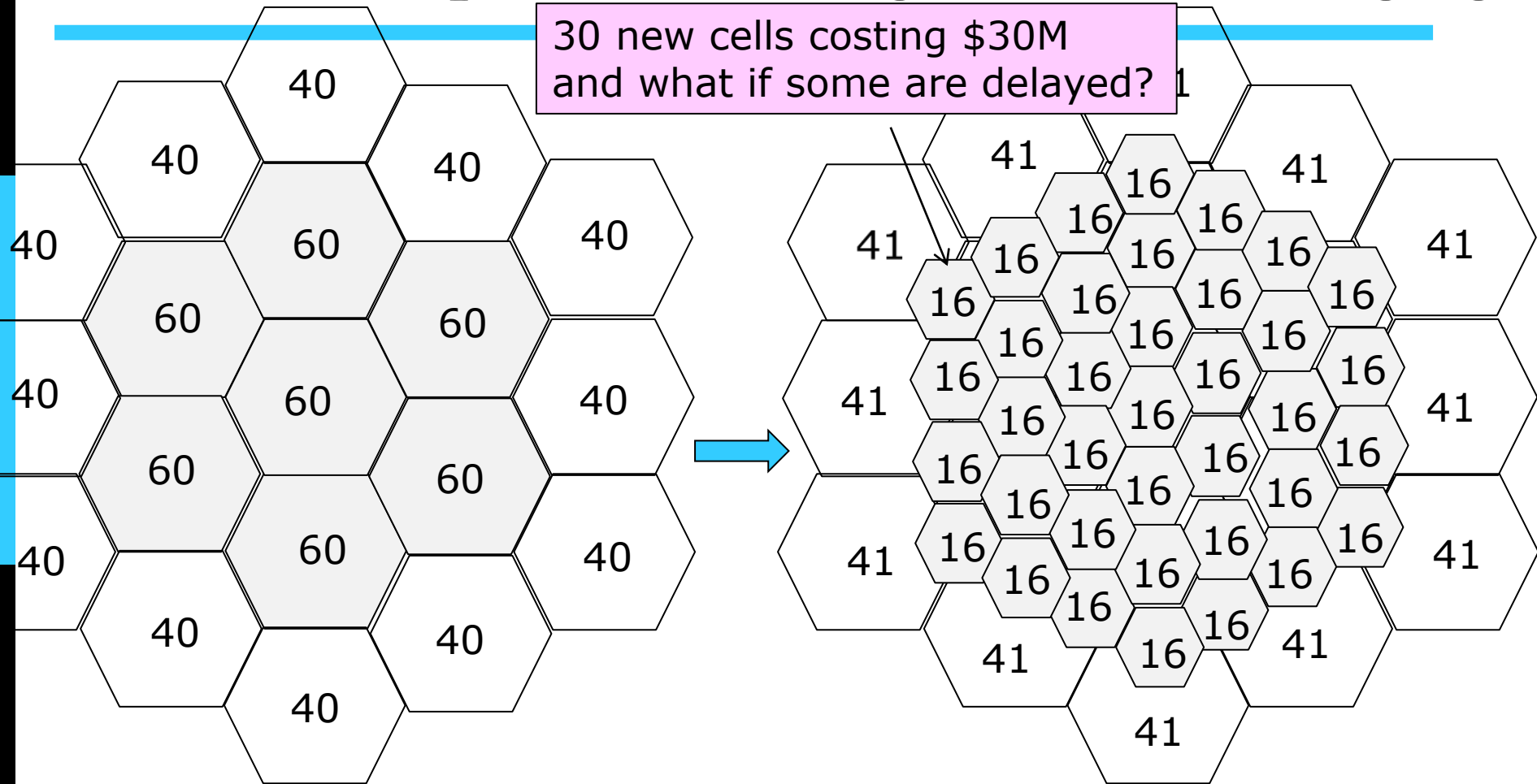
# “Cell splitting” when more capacity is needed

- Preserving the old base stations ●
- New ones in between ●
- Each new cell will eventually have:
  - The same number of channels
  - In 1/4th the area
- So each “cell split” eventually yields a 4x increase in system capacity

Q5

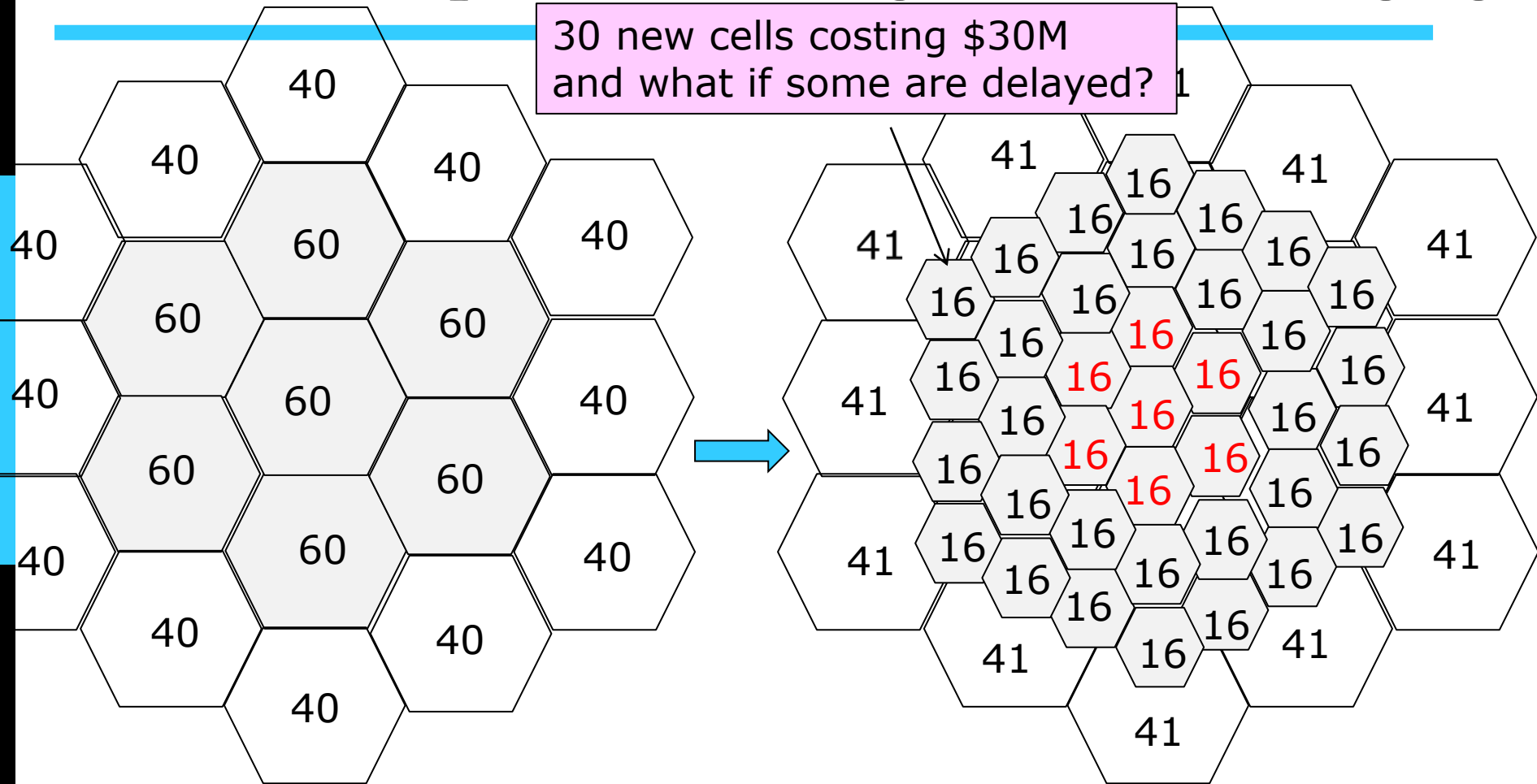


# Replacing the larger cells with smaller cells would be expensive and logistically challenging



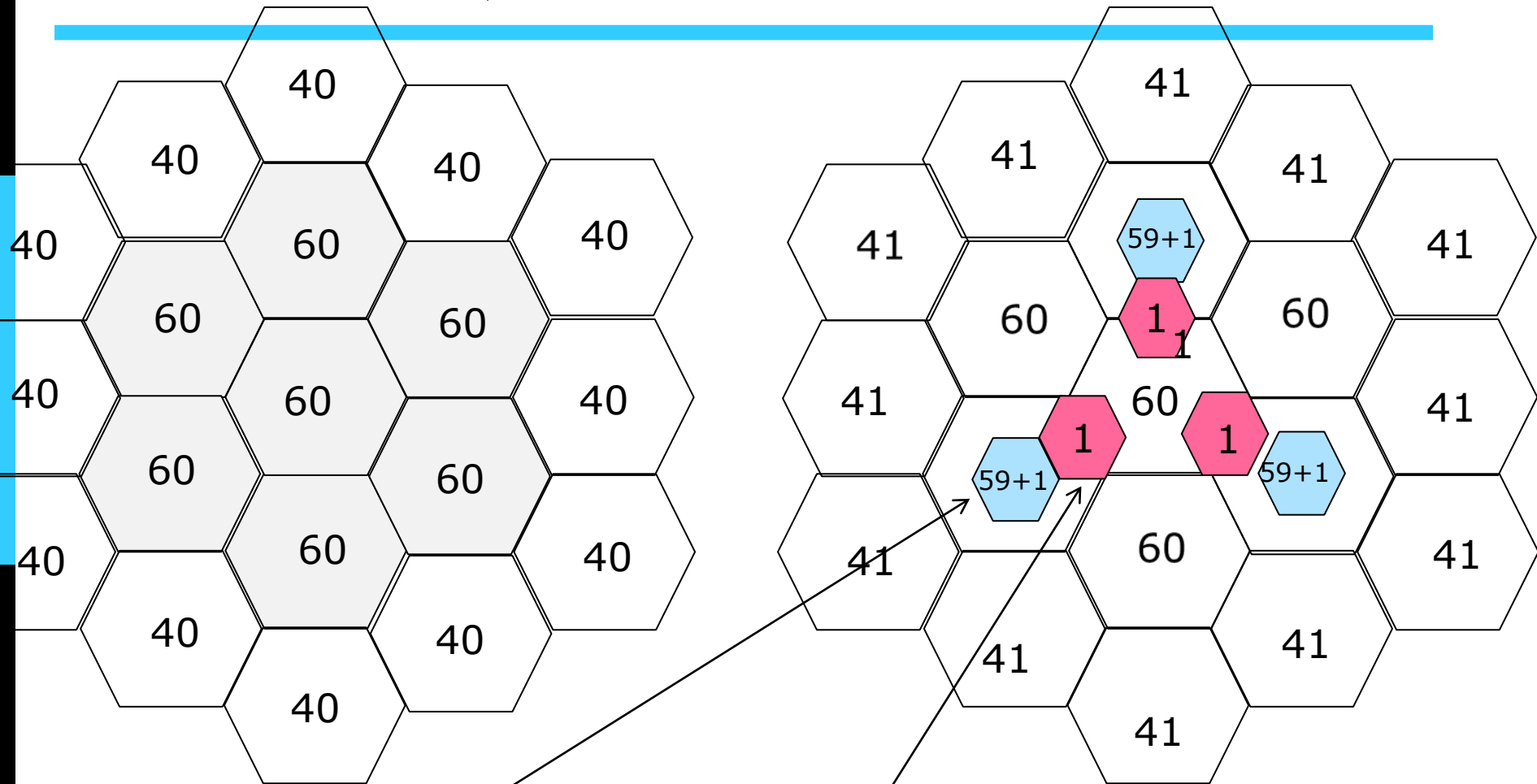
Many new base stations would have to be ready at the same moment.  
They would use at least  $\frac{1}{4}$  of the channels, thus causing more splitting.  
(surrounding cells would have to split very soon)

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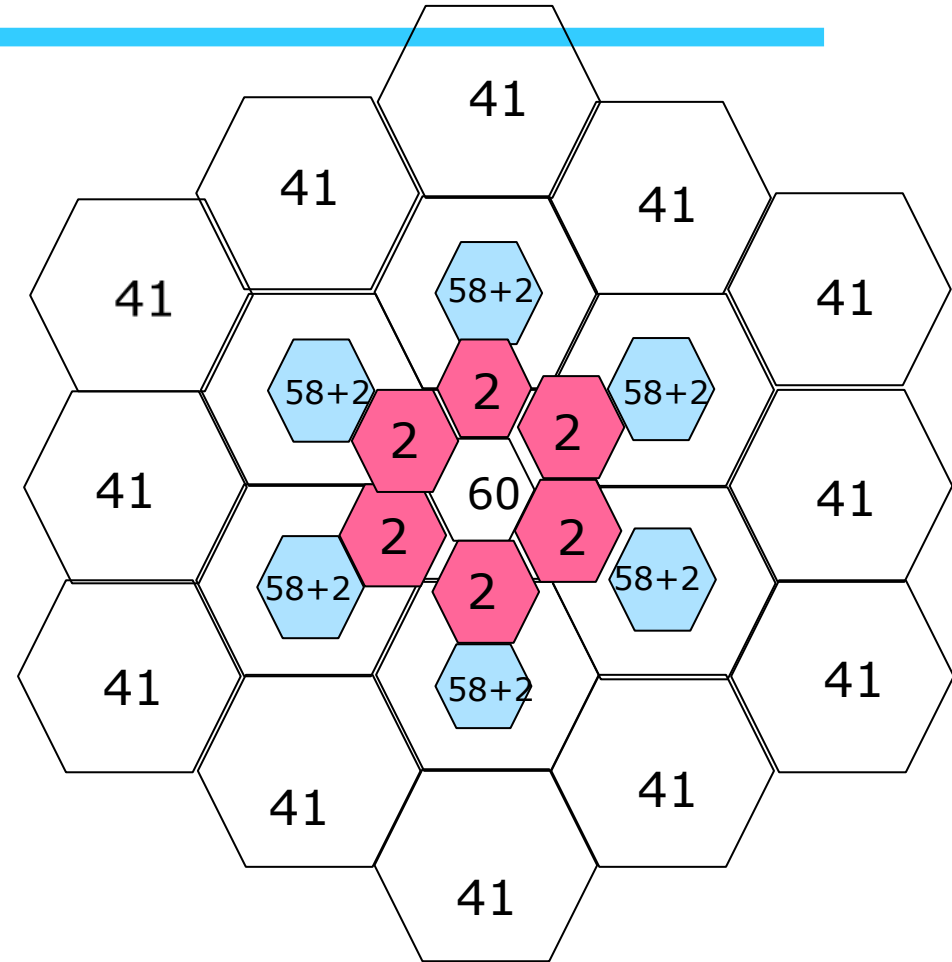
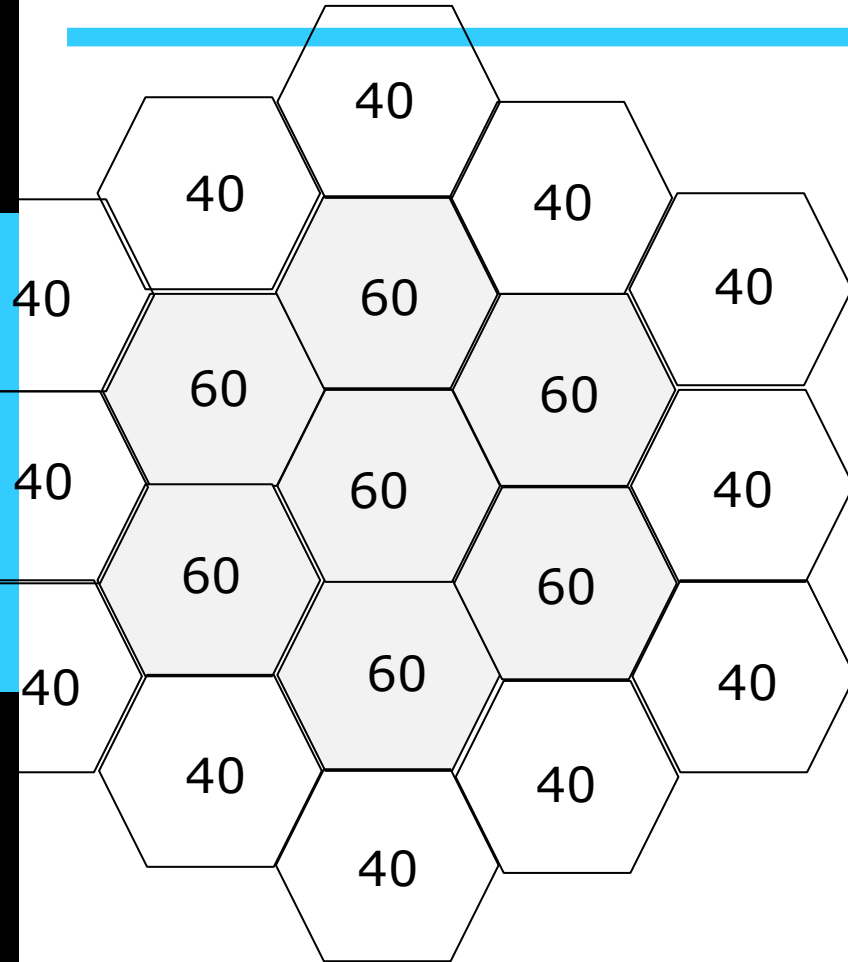
The “old grid” of large cells must remain in operation.  
(It handles most of the calls). The new small cells begin as an  
“overlay” that just serves a bit of “incremental” traffic



3 “old base stations” serve (mostly) their “old” large cell + a bit of traffic in their “**co-sited**” **new small cell**.

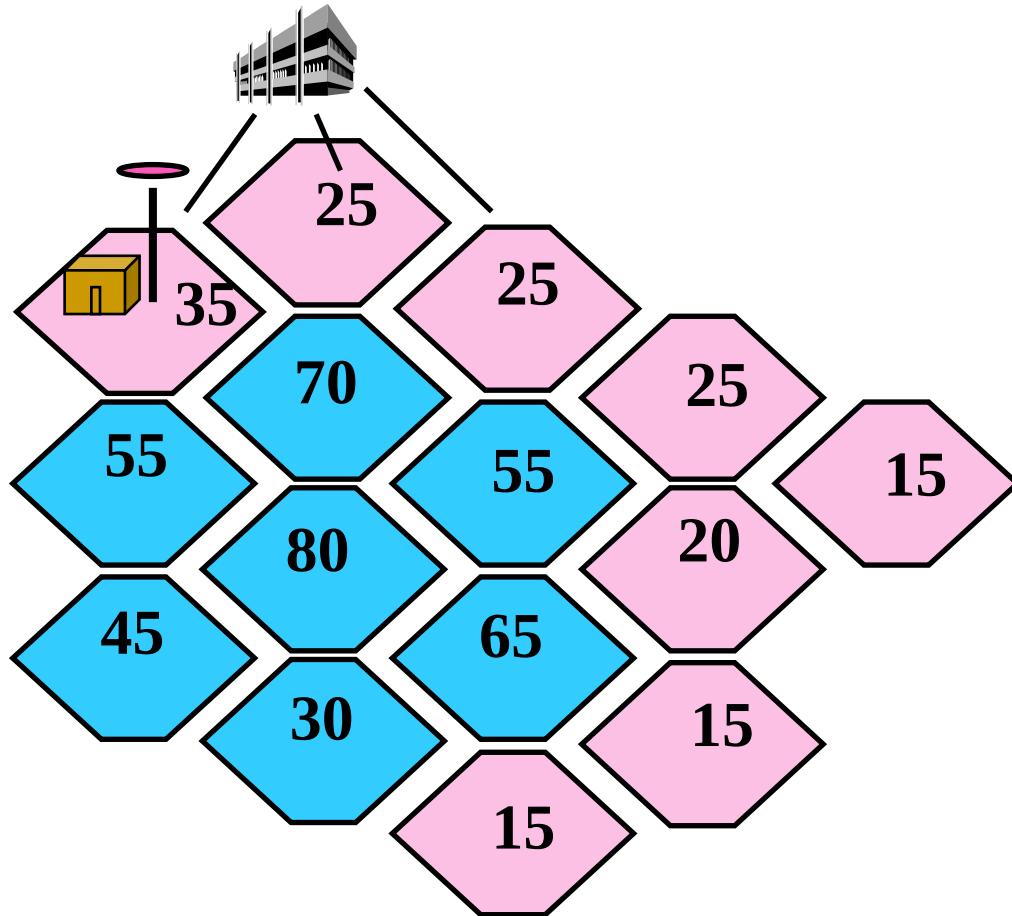
A few “**new base stations**” serve a bit of traffic in their small areas (these 3 channels are the growth)

We gradually add red cells (and to use more channels in those cells) as the system grows. At some point the small-cell coverage is continuous in the central area, and we have some small cells in other areas



The addition of new base-stations is gradual and flexible

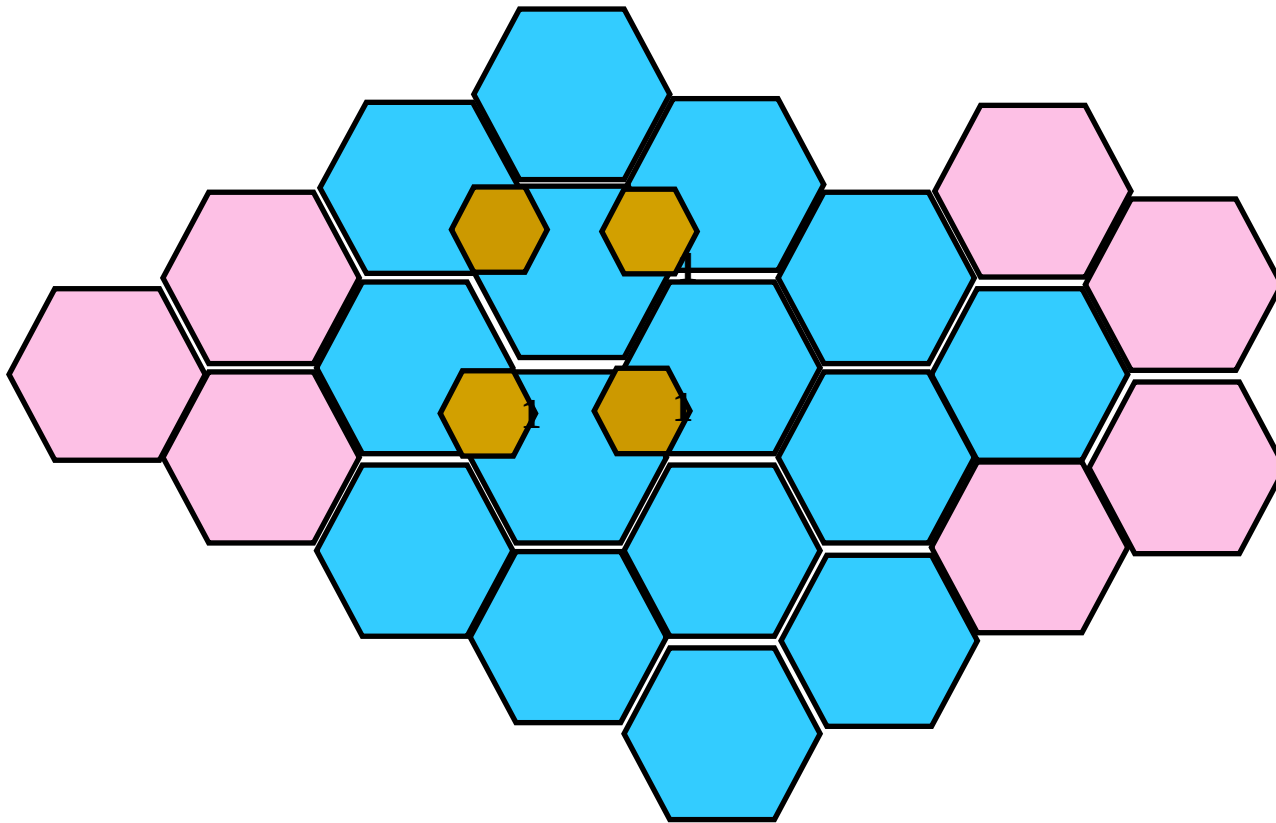
A look at a 400-channel cellular system-  
The largest cells just before they begin to split



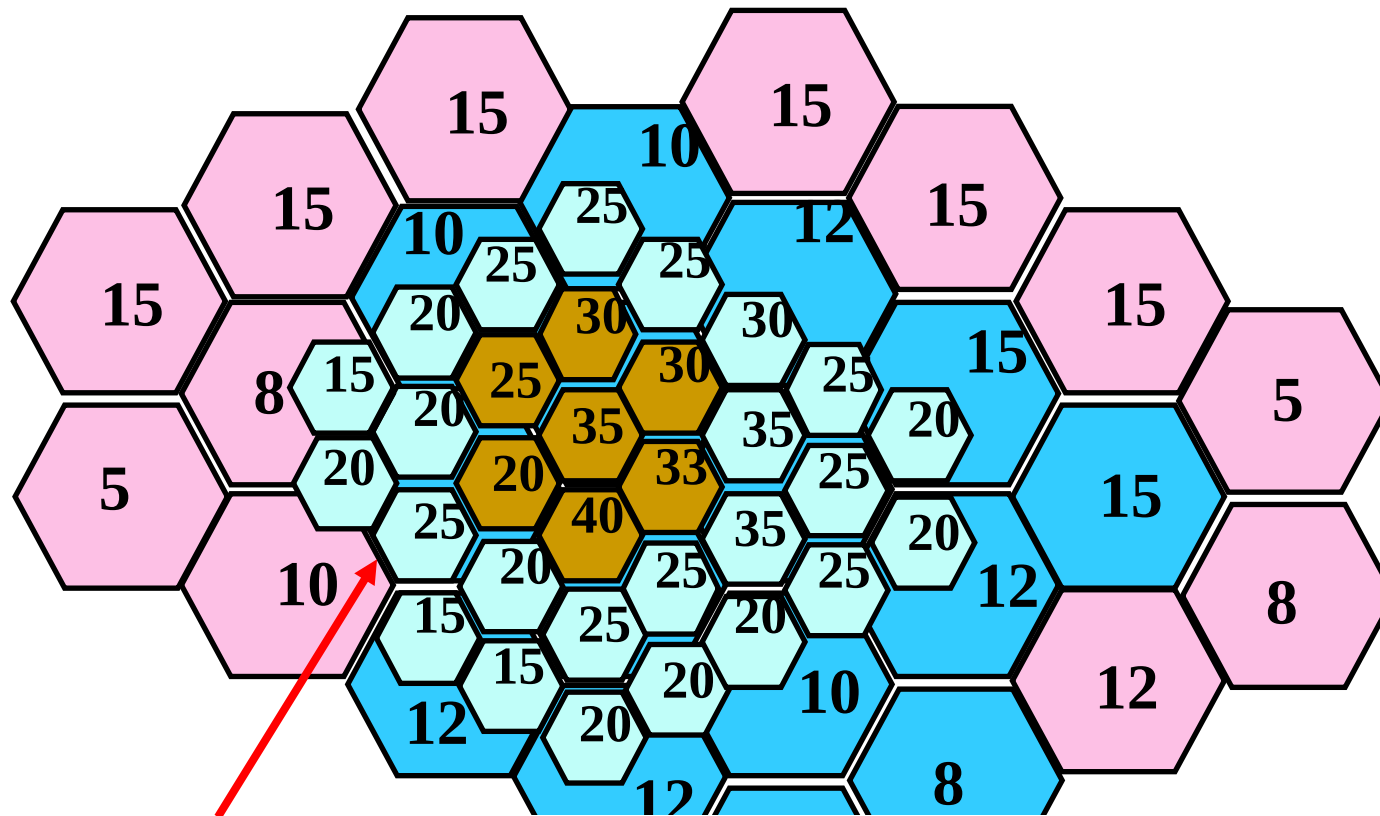
15 cells  
1000 sq miles  
\$15M cost  
15K users  
1000 users/cell  
\$1000/user

# System expands; cell splitting begins

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More expansion and more cell-splitting  
but with multiple cells sizes we get fewer channels/cell

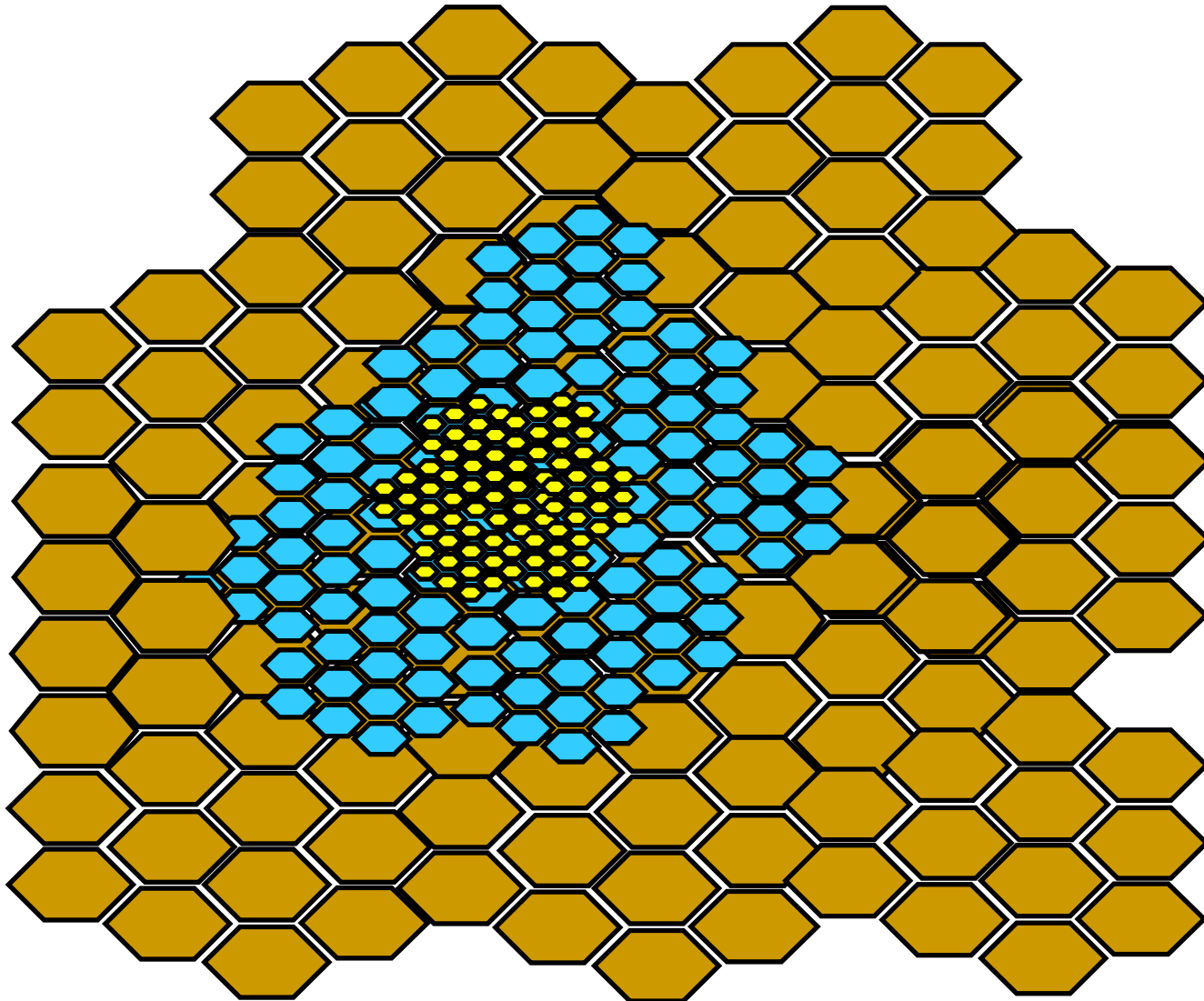


- 60 cells
- 2000 sq mi
- \$60M cost
- 60K users
- 1K users/cell
- \$1000/user

When we have multiple cell sizes, they need different channel sets near the transition. This leads to having about half as many channels per cell (on average). With 400 channels the average cell has  $\sim 30$  channels and 1000 users. This means about 33 users/channel (old systems had  $\sim 60$  users/chan)

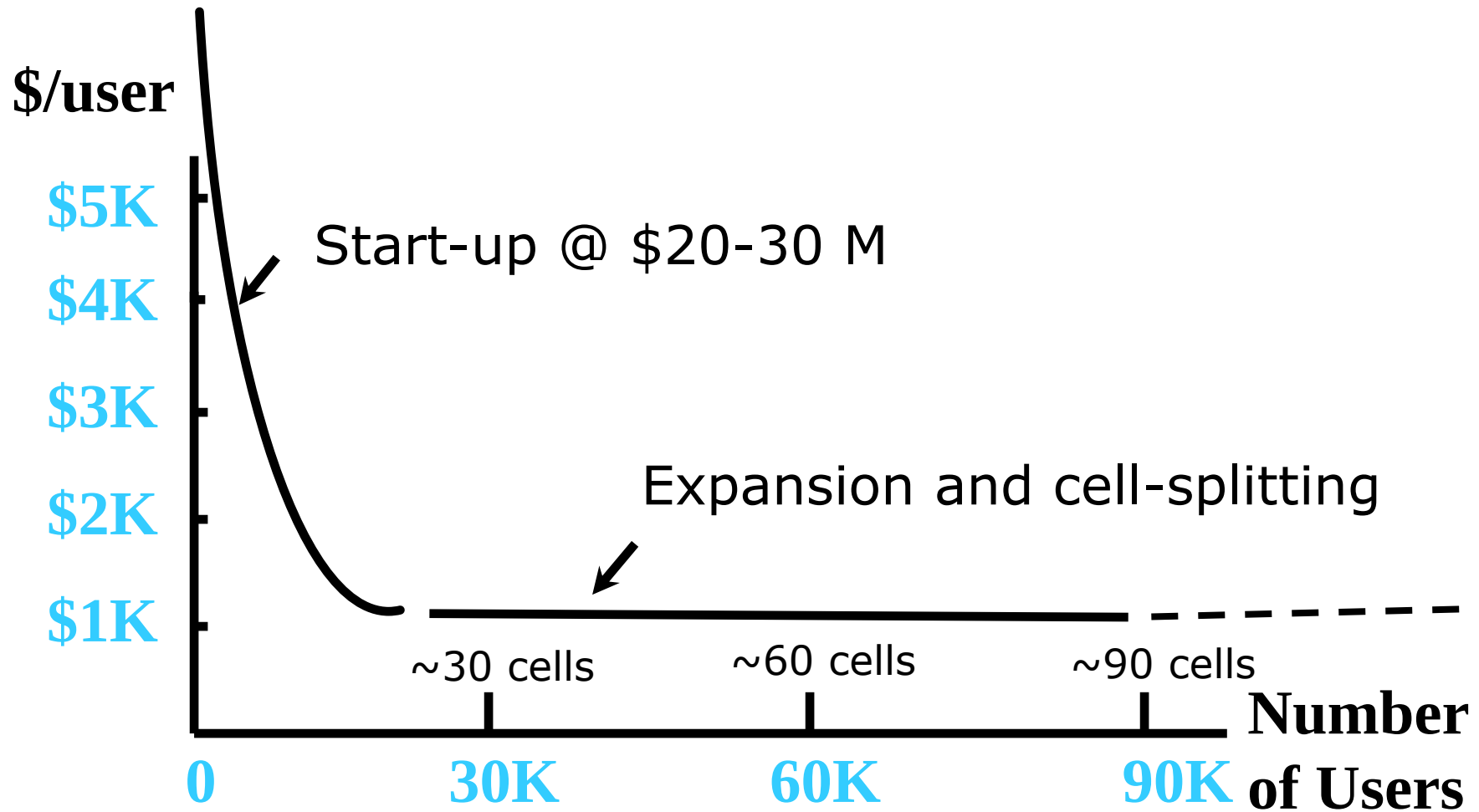
# Mature system- Expansion and smaller cells

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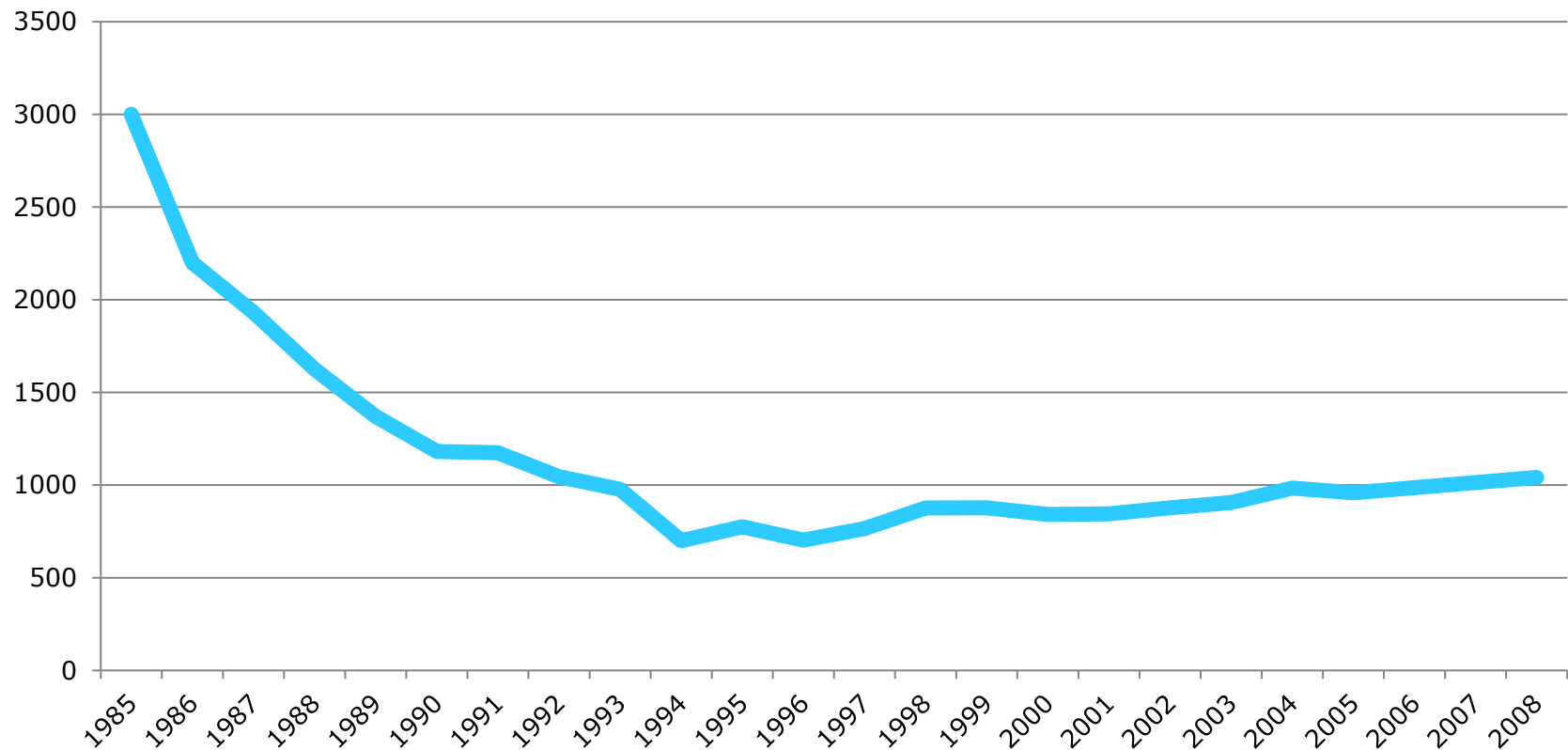
400 cells  
3000 sq mi  
\$400M cost  
400K users  
1K users/cell  
\$1000/user

# The investment per user for a 400-channel system with a 7-cell repeat pattern

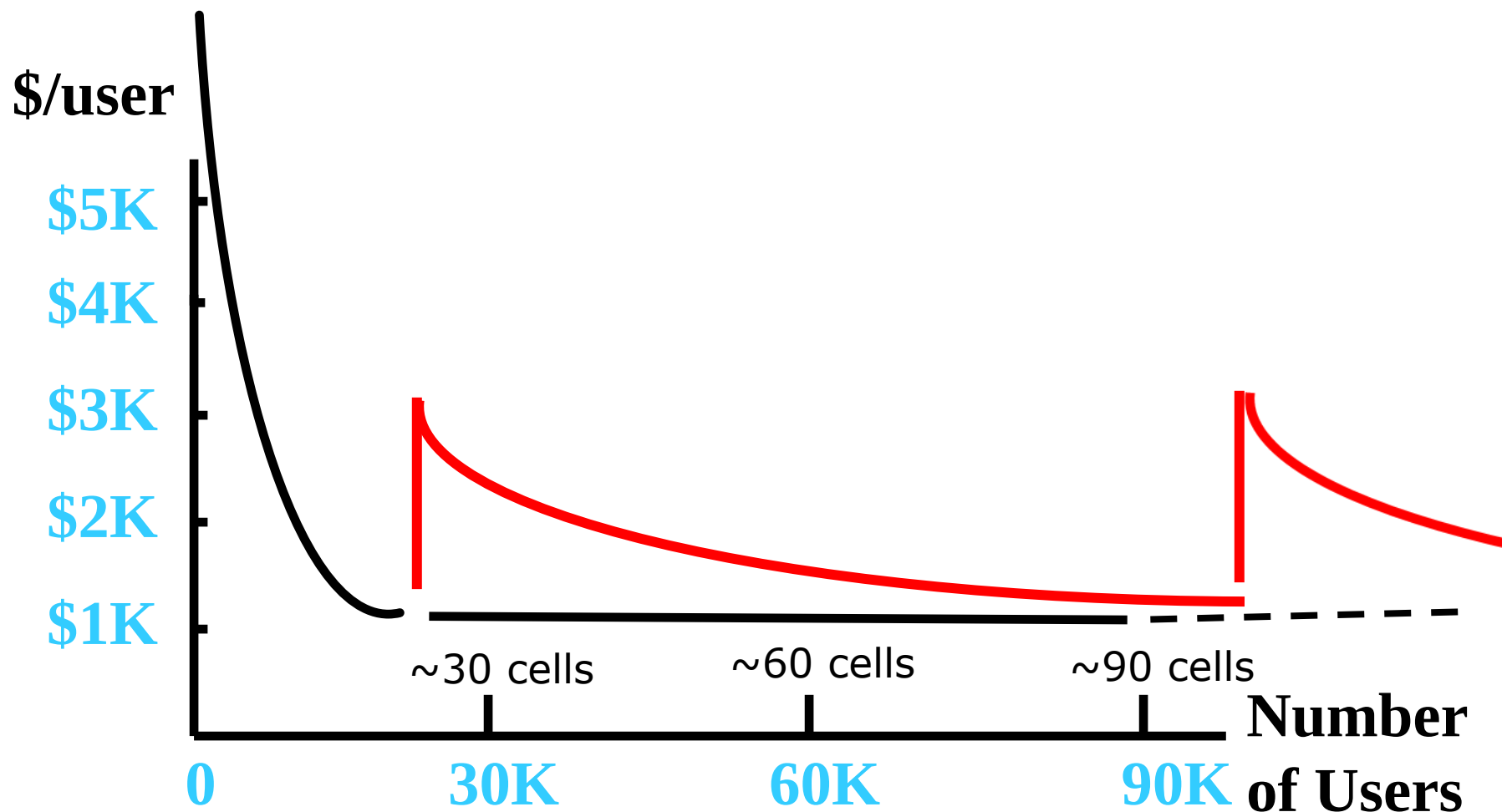


# Checking the CTIA Data

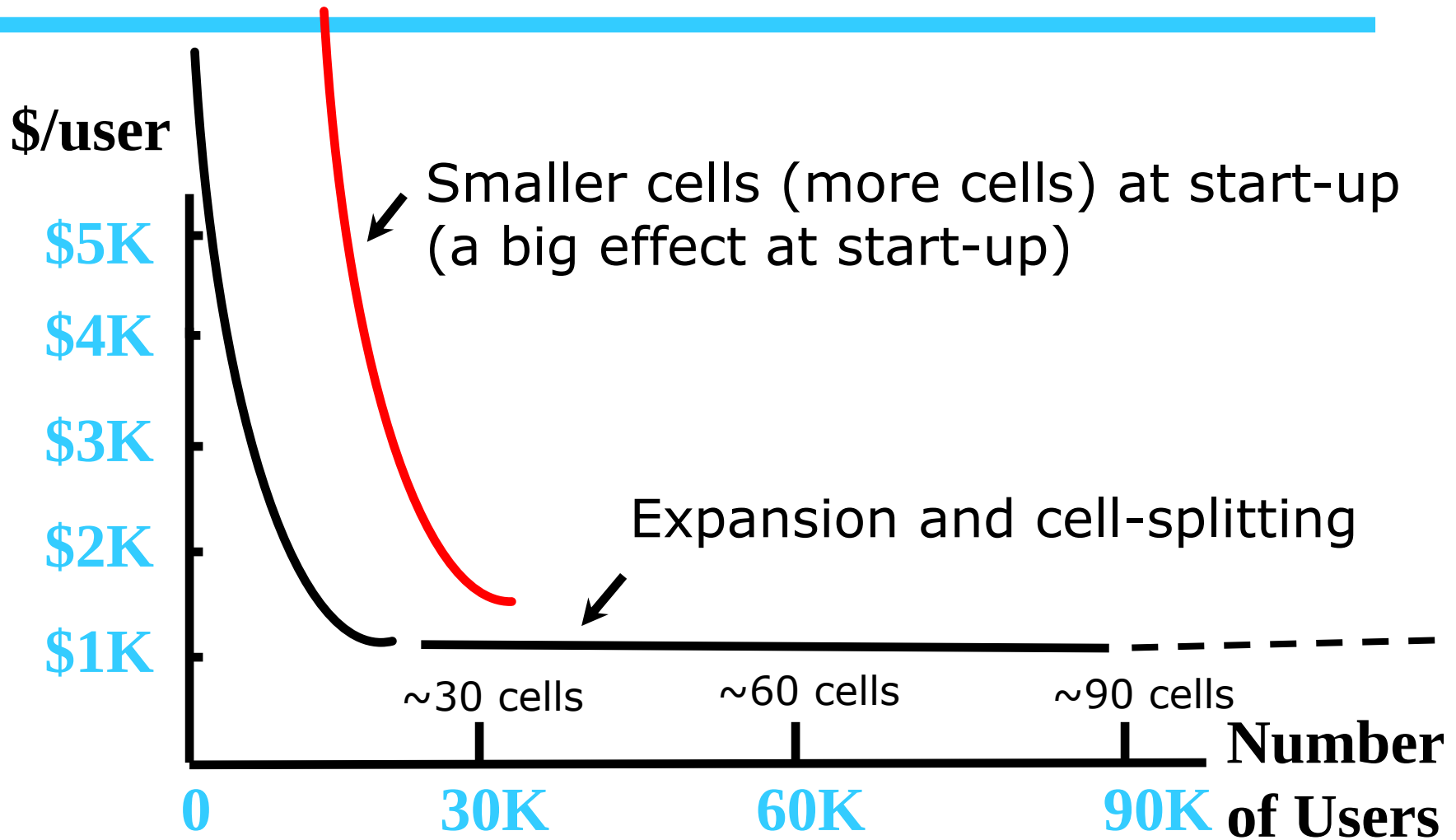
## Investment/user 1985-2008



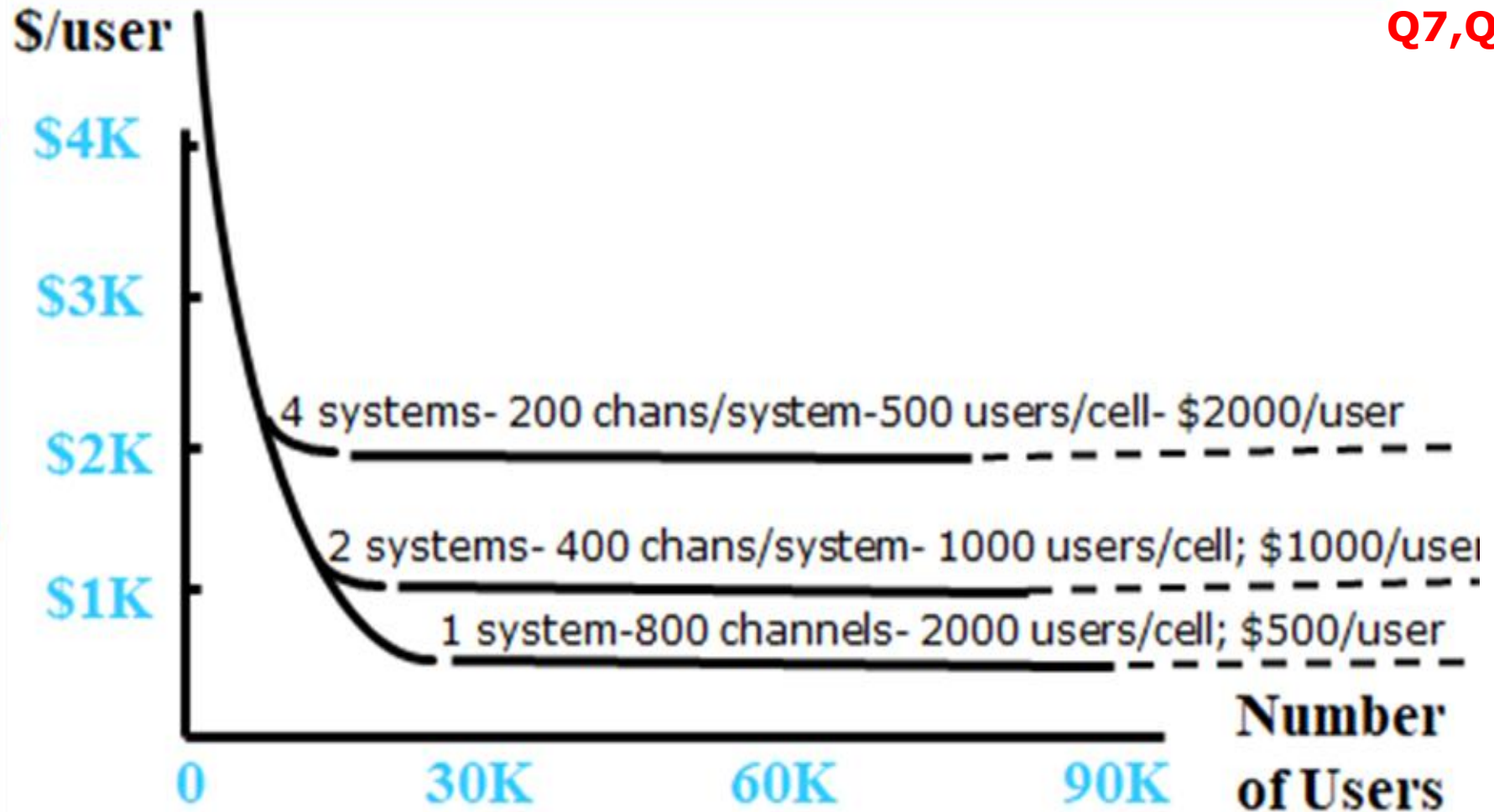
# System cost per user with massive cell-splitting with new cell-size



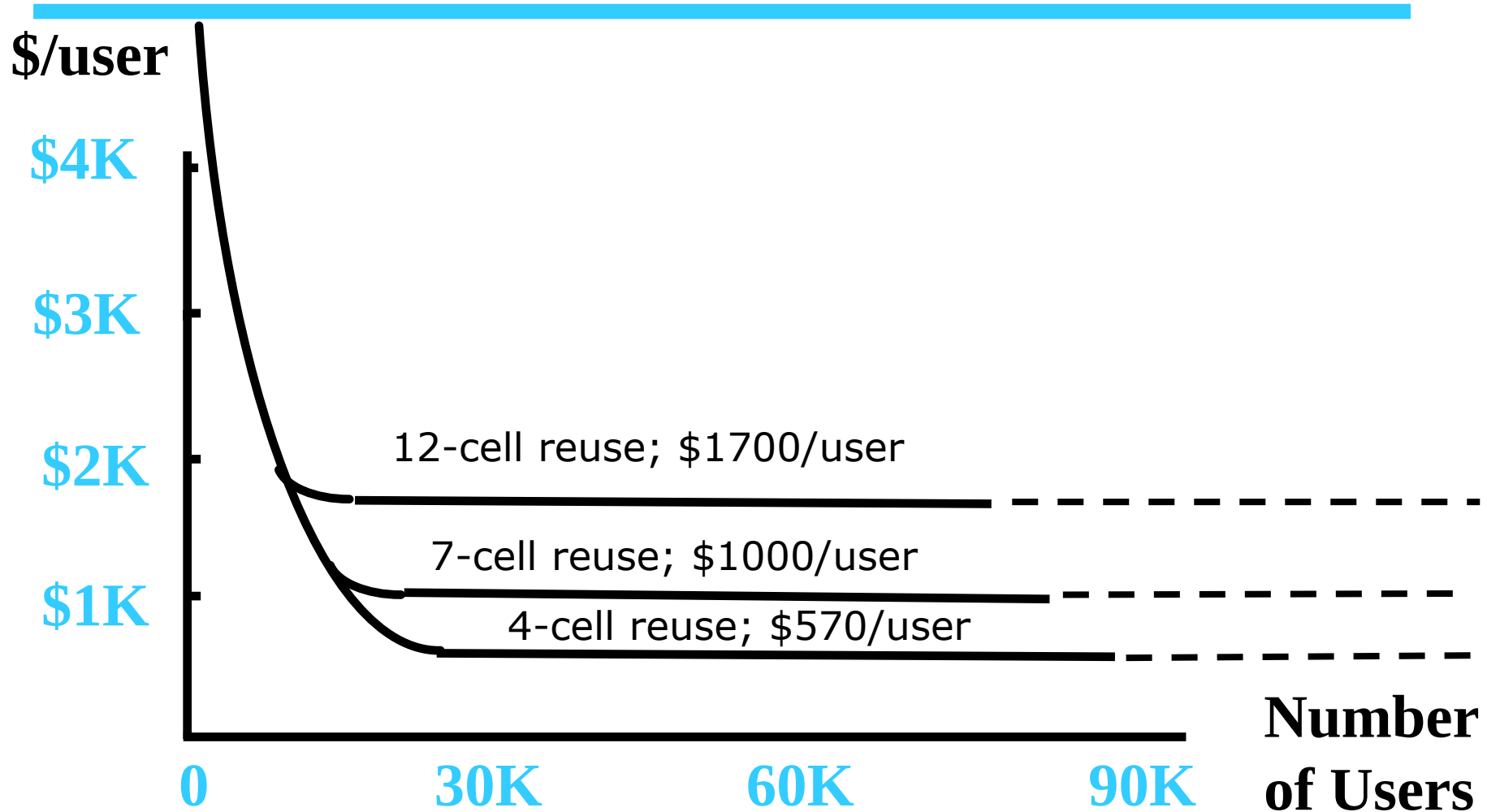
# The effect of starting with smaller cells



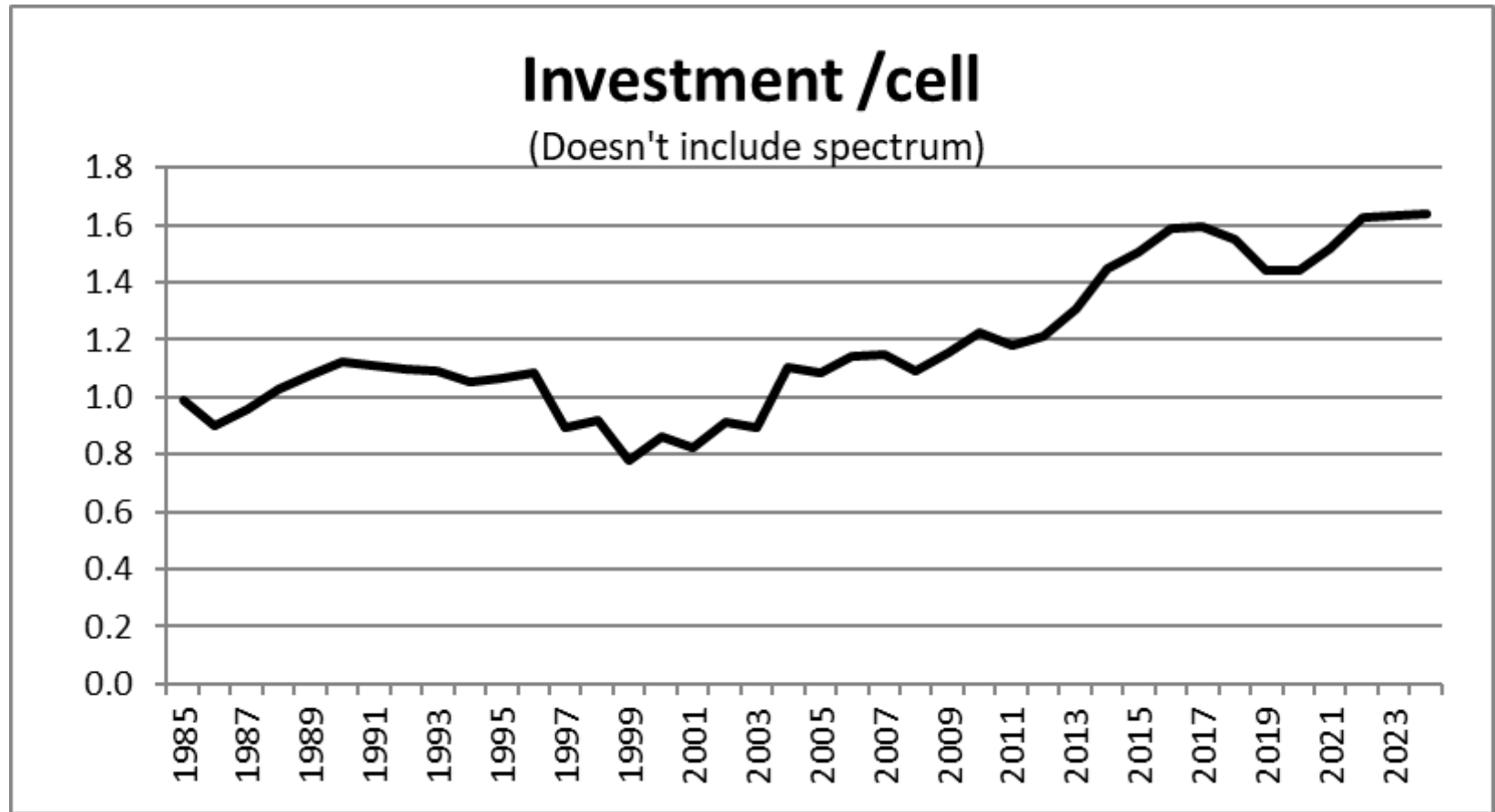
# The effect of getting 800, 400, or 200 channels



The effect of having 400 channels with a 4-cell reuse pattern, a 7-cell reuse pattern, or a 12-cell reuse pattern



# CTIA data until more recently



**Why was the cost of a base station starting to increase after 2021?**

# Next time

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- In the pre-lecture reading for this lecture, we saw that the number of channels would affect the price users pay
- In the next lecture, we will use “financial accounting” to calculate those numbers
  - AT&T would argue that a monopoly would allow the lowest prices for the customer
  - Motorola and the DOJ would argue that competition would create the lowest prices in the long term
  - Both turned out to be right