Bandwidth-sharing in LHCONE

an analysis of the problem

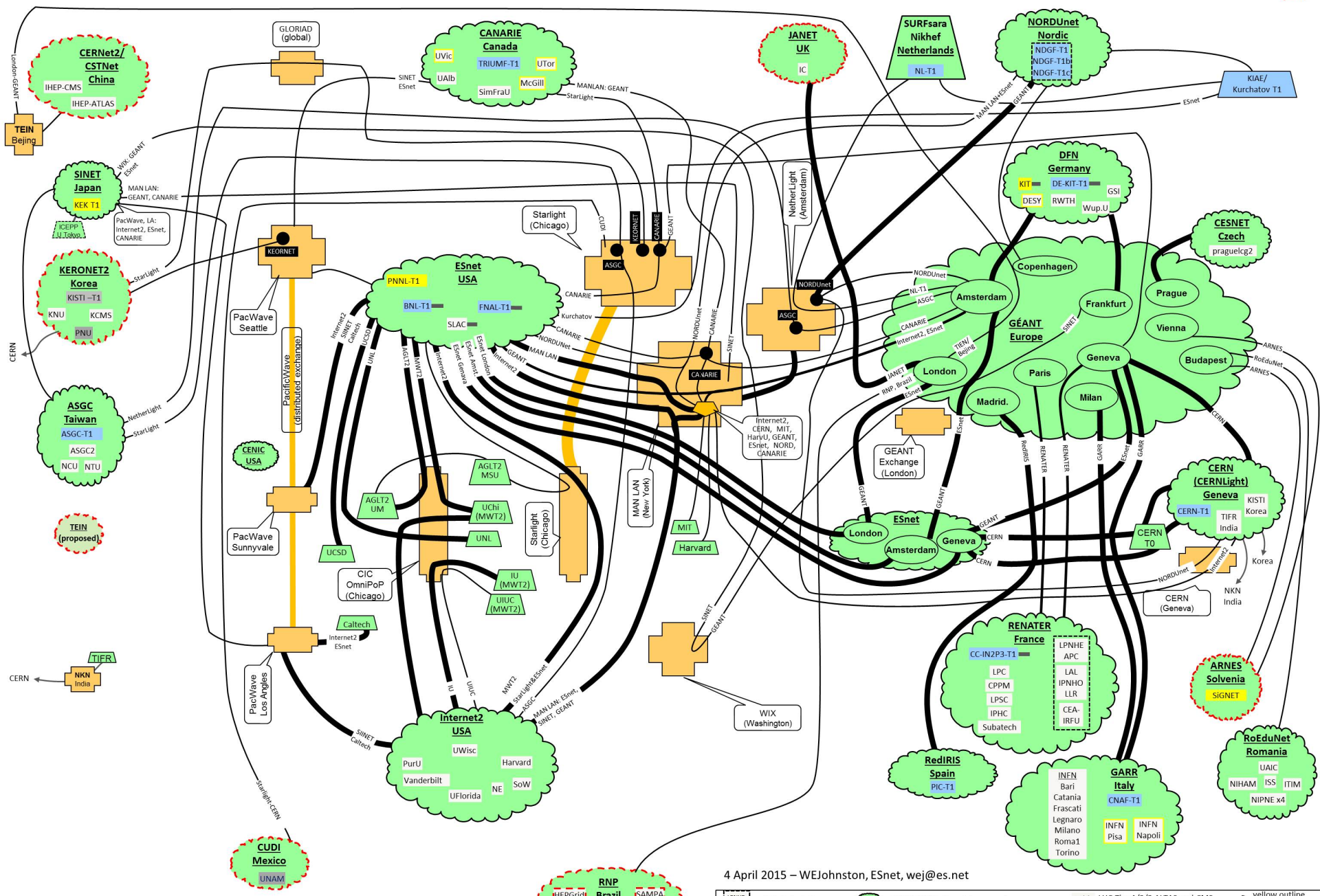
Run-2 vs. Run-1

- Relative reduction in CPU, disk, people
  - Efficiency is becoming more important
- Network now seen as more reliable
  - Stable, performant, well-provisioned
  - Now used as if free and infinite
- Computing models: more relaxed data-placement
  - T2 -> T2 transfers
  - Xrootd data federations for WAN access (CMS: AAA)
  - Significantly more fluid than originally planned

Scheduling the network

- Data-transfer needs are growing
  - Cannot assume the network will remain free and infinite forever
- Computing models are evolving
  - Increasingly close interaction with h/w resources
  - Broader range of resource-types (opportunistic, cloud, volunteer) with different storage & I/O characteristics
- Can see the value of scheduling network use
  - Just-in-time data-placement, deadline management
  - Possibilities that come from deterministic behaviour, not necessarily just more speed

LHCONE: A global infrastructure for the High Energy Physics (LHC and Belle II) data management



4 April 2015 – WEJohnston, ESnet, wej@es.net

Distributed site
Pending LHCONE connection
Sites connected at 40G-100G
LHCONE VRF domain/aggregator
Network provider / exchange point router
Cross-border router
Regional R&E communication nexus
UChi LHC Tier 1/2/3 ALTAS and CMS
KEK Belle II Tier 1/2
PNU LHC ALICE or LHCb
UNL Sites that are standalone VRFs,
yellow outline indicates LHC+Belle II site

Schedule, but how?

- How to allocate bandwidth fairly & efficiently to users with different & time-dependent needs?
- Candidate technologies, won't discuss here
  - Virtual circuits, multi-path flows
  - Bandwidth guarantees can be hard or soft
  - Networking groups are making progress towards a technical solution
- Then you get a new problem: oversubscription
  - Common to all successful middleware:
    - phase 1: make it possible, phase 2: stop users abusing it!

A good bandwidth-sharing system?

- Automatic, lightweight
  - Set up circuits automatically, but only where needed
  - Participation not mandatory (casual or low-load users)
- Elastic, responsive
  - Shares can grow and shrink over time
  - Change on timescale of ~1 hour to follow needs
- Efficient, fair
  - Allows maximal use of bandwidth at all times
  - Short-term &long-term: no starvation, no hogging
- ~~Fixed quotas~~

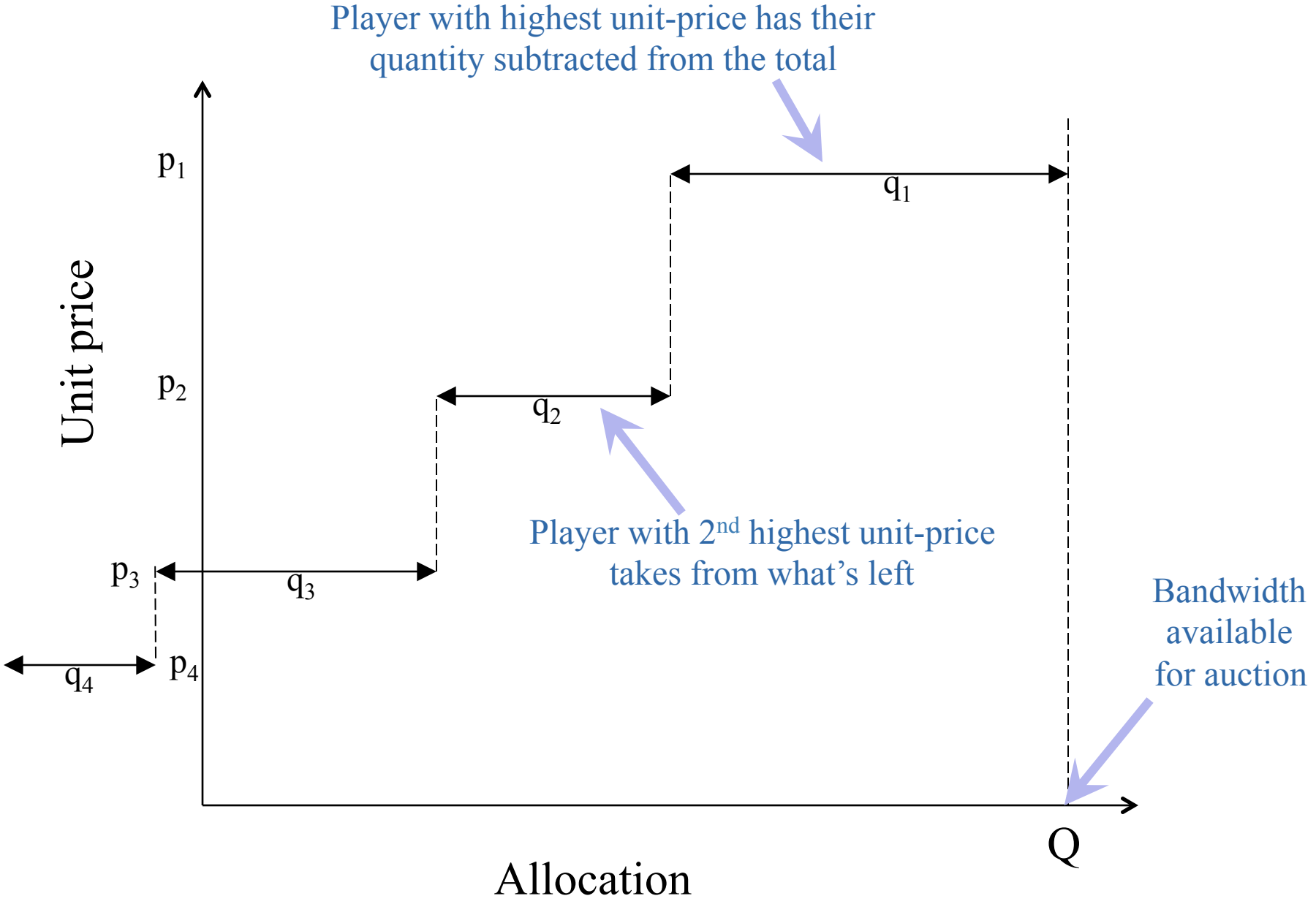
High-level requirements: we want…

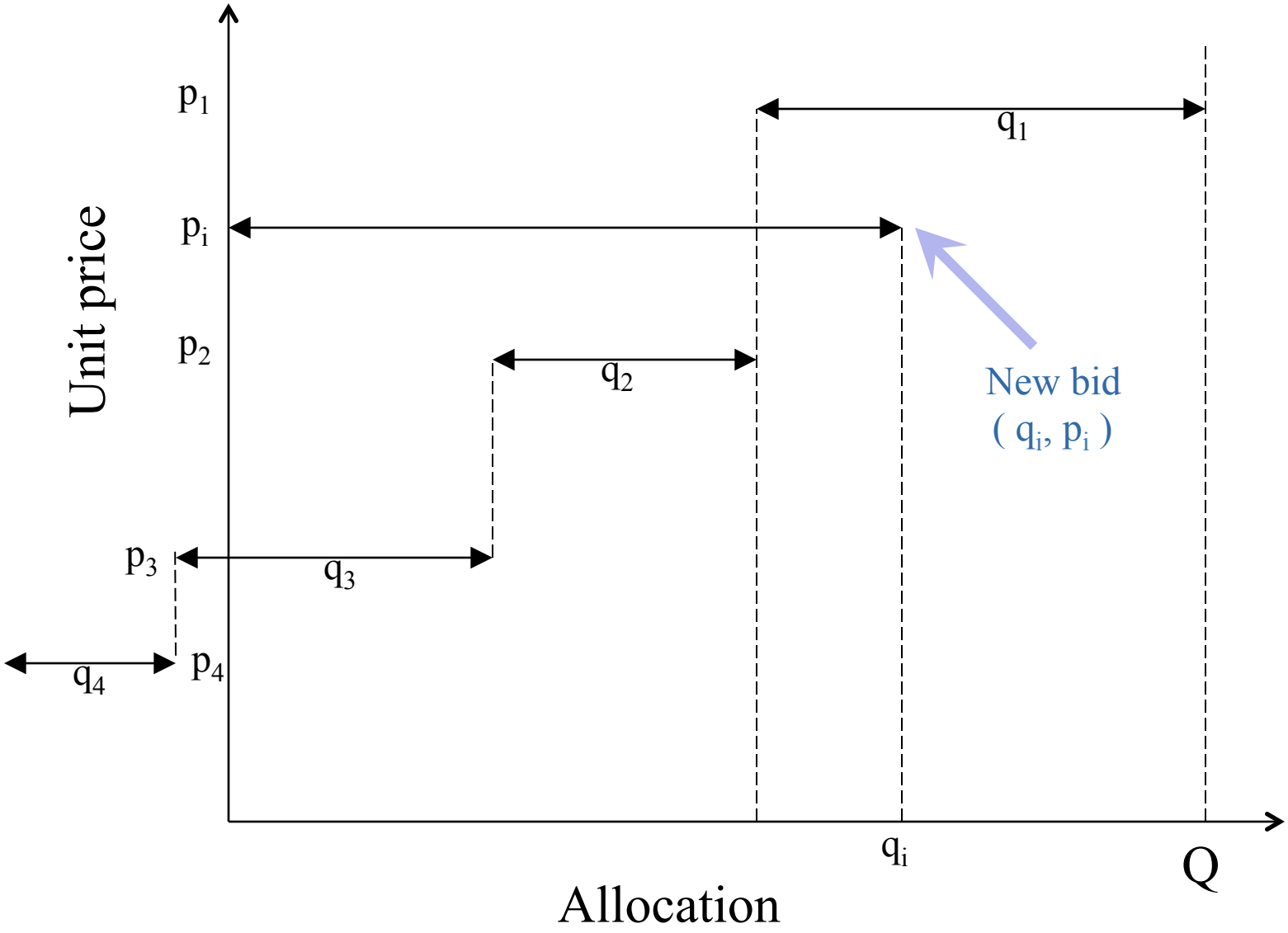
- A way for users to tell LHCONE their needs
  - At any time, across the whole of the LHCONE network
- To resolve over-subscription, quickly & fairly
- Technology to implement the shares
  - (out of scope of this talk)

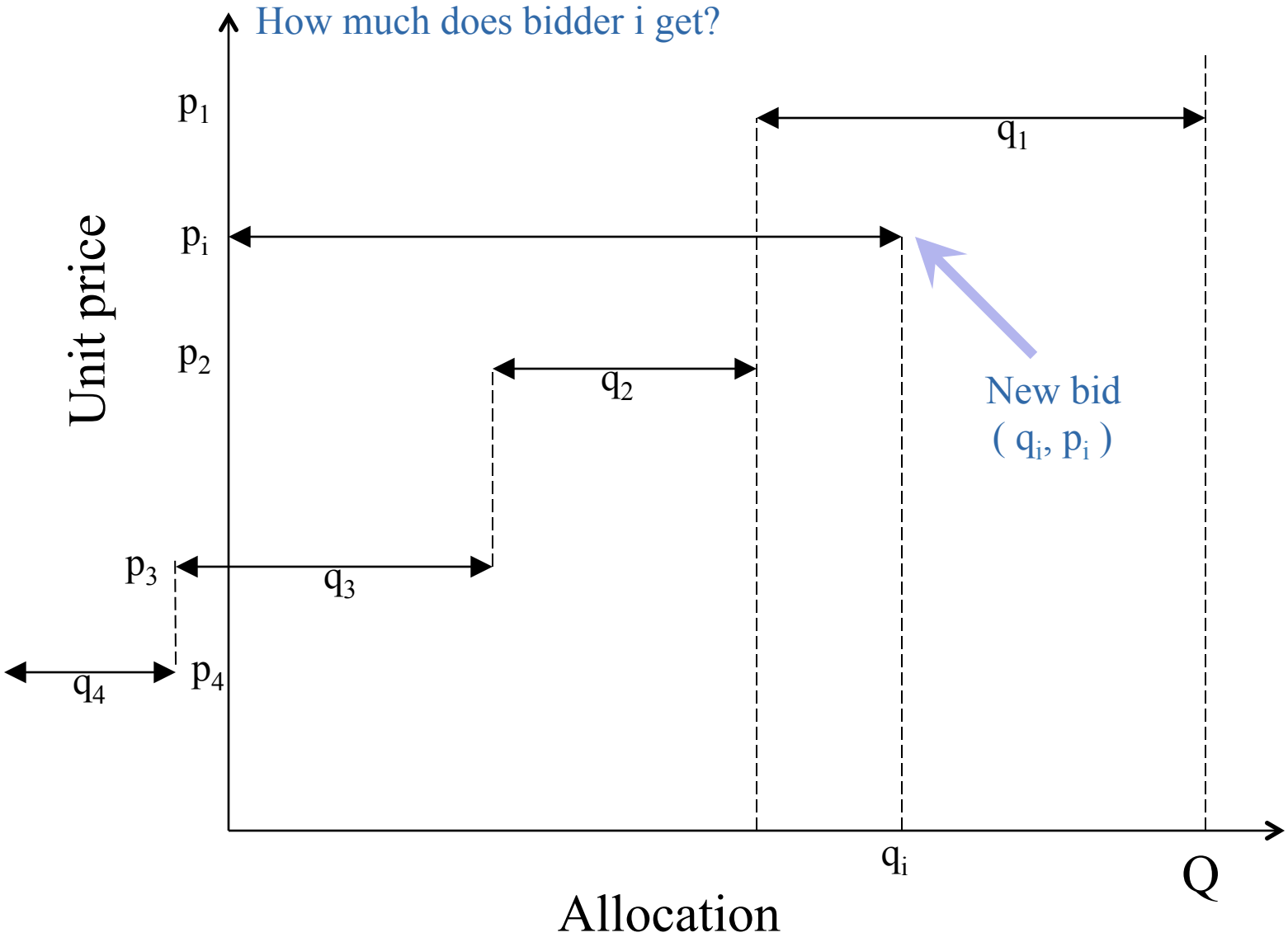
- Candidate solution, the *Progressive Second-price Auction* (PSP)

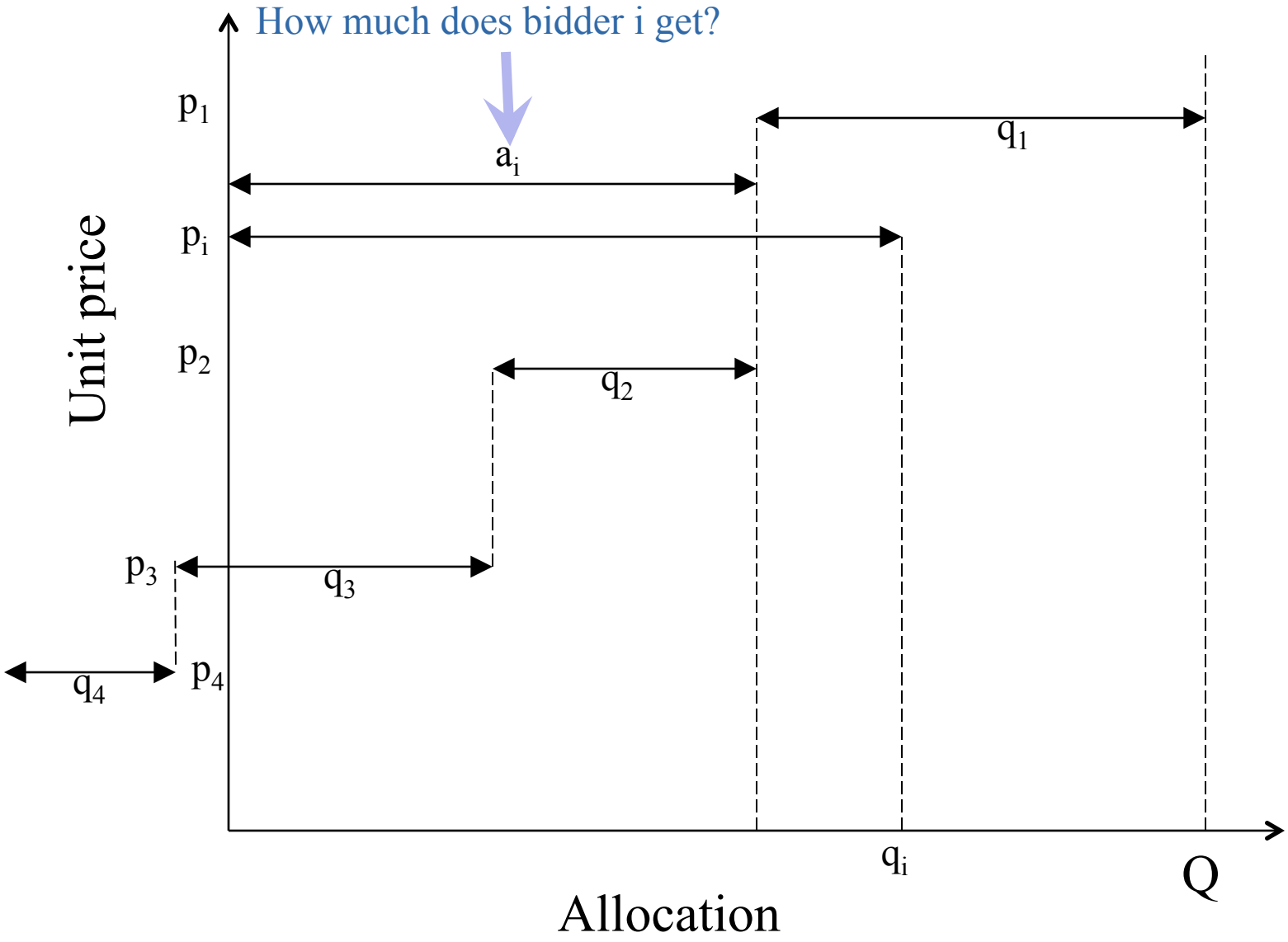
How does it work?

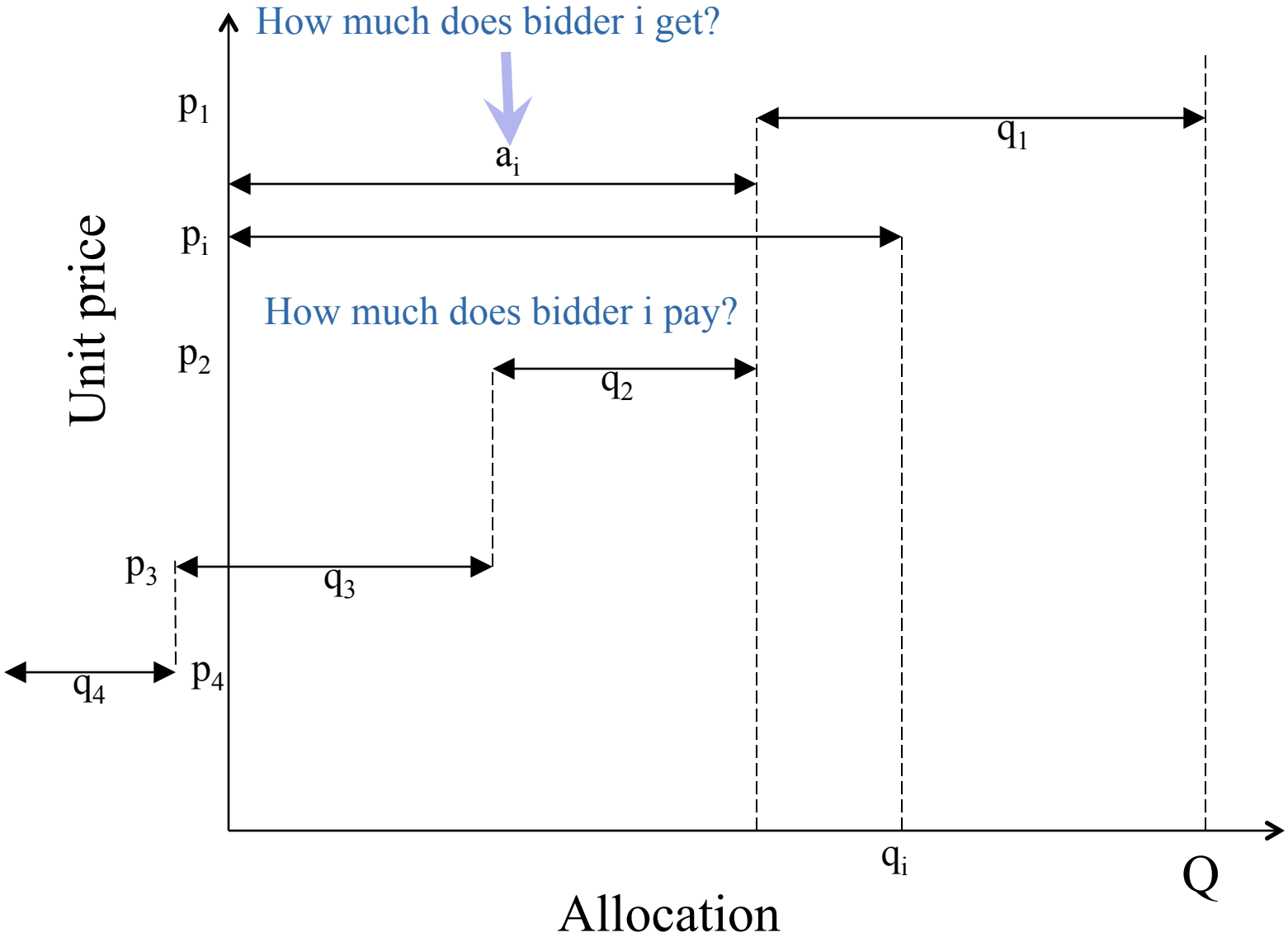
- Network offers bandwidth **Q** on a given link
- Bidders have fixed budget (varies per bidder)
- Bidders specify a quantity and a unit-price: $(\mathbf{q_i},\mathbf{p_i})$
- PSP calculates allocation & total cost: $(\mathbf{a_i},\mathbf{c_i})$
- PSP sends all allocations/costs to all bidders
- Bidders revise their bids, submit them again
- Repeat until convergence
- Convergence guaranteed for rational bidders

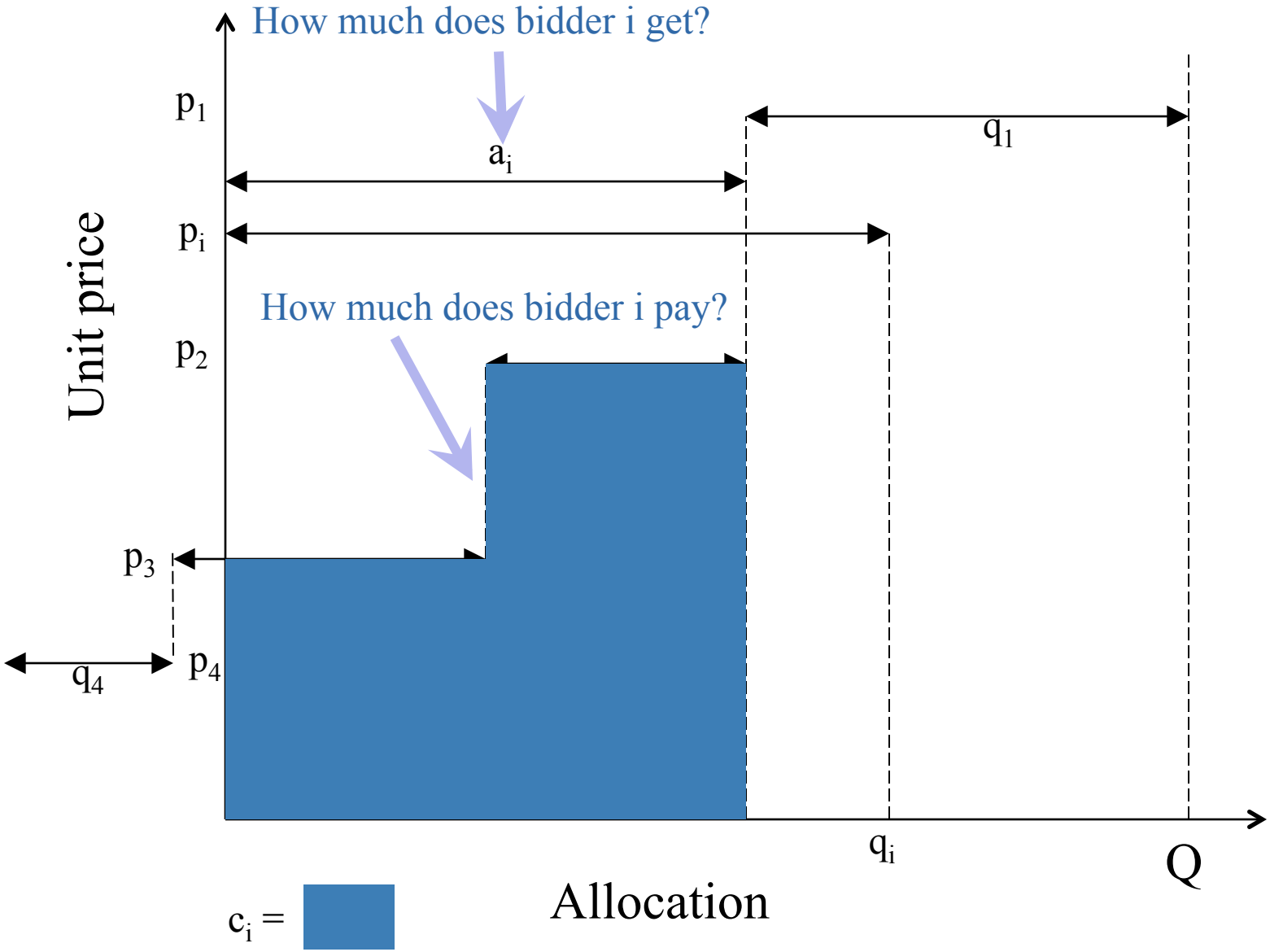

Player with highest unit-price has their quantity subtracted from the total
Unit price
p1
p2
p3
p4
q1
q2
q3
q4
Player with 2nd highest unit-price takes from what's left
Bandwidth available for auction
Q
Allocation


Unit price
p1
pi
p2
p3
p4
q1
q2
q3
q4
New bid
(qi, pi)
qi
Q
Allocation


How much does bidder i get?
Unit price
p_1
p_i
p_2
p_3
p_4
q_1
q_2
q_3
q_4
New bid
(q_i, p_i)
q_i
Q
Allocation


How much does bidder i get?
p_1
a_i
q_1
p_i
p_2
q_2
Unit price
p_3
q_3
q_4
p_4
q_i
Q
Allocation


How much does bidder i get?
p_1
a_i
q_1
p_i
Unit price
How much does bidder i pay?
p_2
q_2
p_3
q_3
q_4
p_4
q_i
Q
Allocation


How much does bidder i get?
p_1
a_i
q_1
p_i
Unit price
How much does bidder i pay?
p_2
p_3
q_4
p_4
q_i
Q
Allocation
c_i =

PSP on LHCONE?

- PSP extends naturally to multiple links
  - Decentralized, independent auction on each link
  - Bidders have fixed global budget
  - Best strategy is to bid for same bandwidth on each link
  - Bidder offers a price per link dependent on the competition for that link
  - Can show that it still converges if bidders are rational
- Repeat auction whenever conditions change
  - After some ‘lease-time’, to prevent chaos - ~1 hour?

Practicalities: budgets…

- Real world, real money
  - Budgets set by bidders
  - PSP guarantees the bidders converge on a solution
- LHCONE, HEP experiments, fake budget
  - Must ensure ‘fake money’ has real value in the auction
    - Must have just enough to express needs coherently
  - How to set the budgets?
    - Budget spent ~every time you win a slice of an auction, need to reset/adjust periodically, to keep the bidders solvent
    - Similar problem to allocating batch quota on shared farms?

How, and how often, to update budgets?

- Reset budget per-auction?
  - No incentive not to spend entire budget every time
  - Can lead to wasteful bidding, where not needed
- Carry-over of unspent budget?
  - Budget-hoarding => undesirable/'unfair' outcomes
- Excess budget
  - Blocking tactics, bidding for a link you don't need
  - Some way to penalize for under-used circuits?
- Needs simulation, with various bidding strategies
  - Budget adjustment musn't destroy auction fairness

Conclusion: principles

- Bandwidth-allocation at LHCONE requires a mechanism which is fair, efficient, lightweight, responsive and automatic
- The Progressive Second-Price auction offers this
  - Users negotiate among themselves how much bandwidth they should get
    - Repeat auction as needed, follow fluctuations automatically
  - Network providers get clear statement of what users want at any point in time
    - No negotiations between experiments & network providers

Conclusion: practicalities

- Fake budget complicates things
  - Setting initial budgets, refreshing budgets periodically
  - Similarities to batch quotas?
  - (can we just charge real money instead?)
- Bidding strategies
  - Coupled to how budgets are managed
  - Possible learning behaviour in repeat auctions
  - Need to understand how budget allocation interacts with bidding strategy to keep the auction truthful