Simple adaptively-prioritised spatially-reusable medium access control through the Dutch auction: Qualitative analysis, issues, challenges

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Outline

Auctions: Why?

- Auctions have long been used (in 193 A.D. the entire Roman Empire was auctioned by the Praetorian guard... but the winner was beheaded 2 months later!)
- Reasons for choosing auctions include:
  - speed of sale or allocation
  - discovery of the true “value” of the offered object
  - transaction “transparency” (fraud prevention)

Auctions for medium access: Why?

- MAC auctions allocate channel to those that value access the most (“prioritised access”)
- A terminal’s valuation of access could either
  - represent the “true” “willingness to pay” of a user, or
  - be a “priority” index computed/adjusted by software
  - priority may be “adaptive”, depending on packet or application type, location, channel state, distance travelled, battery status, etc.
- Auction-based MAC is “incentive compatible”: needs not rely on “etiquette” or “altruism”

“sealed bid” MAC auctions

- A MAC auction should be relatively simple and fast
- Previous proposals resemble “sealed bid” auction
  - each bid is independently submitted in a “sealed envelope”
  - envelopes are opened simultaneously
  - highest bidder wins, and pays as specified by the rules.
- Problems with MAC sealed-bid auctions
  - require an auctioneer (controller)
  - require another MAC protocol to receive the bids.
  - With a large, variable no. of bidders, the bid protocol may
    - waste system resources, if contention-free, or
    - miss important bids, if contention-based (the highest-value terminals may be unable to make a bid)

The Dutch auction

- Public “clock” displays a progressively falling price
- Participants silently watch and wait
- Eventually participant that most values object “takes it”

Dutch auction for MAC: why?

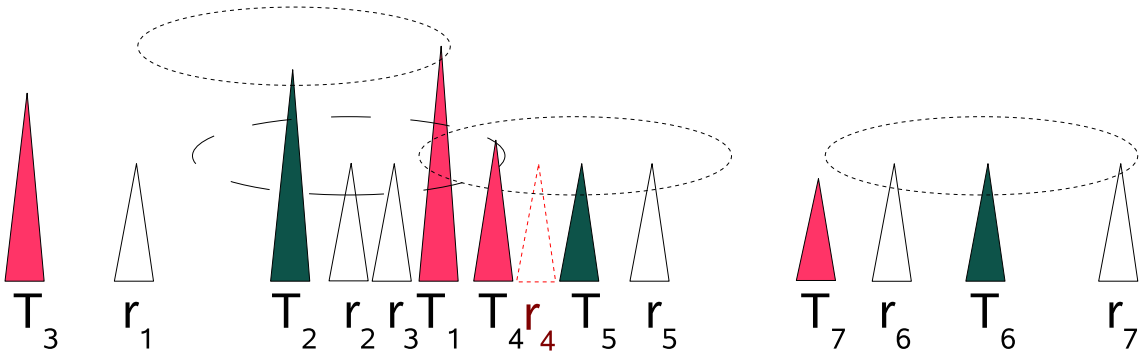
This auction retains simplicity and speed, and add:

- own bid-making protocol that prioritises highest bid(s)
- the possibility of a distributive implementation (start times, initial price, and rate of decrease can be pre-specified; then a terminal can determine from own clock the auction status)
- Confirmation of transmitter-receiver pairs, with smooth continuation if the pair is infeasible
- exceptional signalling economy

Simple MAC for synchronised Ad Hoc Networks

- Synchronisation enablers: GPS, cellular and “cognitive” pilot signals, periodic connection to wired network, etc.
- General schedule
  - At t_0 1st auction starts at pre-specified price, and time-rate of decrease, and lasts τ
  - At $t_0 + \tau$ the first winner(s) use medium for T time units
  - At $t_0 + \tau + T$ another auction starts, etc
- 3 short messages necessary for successful winning
  - the winner sends its ID and that of the desired receiver
  - the receiver, if available, sends a short confirmation
  - the winner announces the successful pairing.
- If the transmitter-receiver pairing fails, auction continues
- The “tick” of the “clock” must allow the 3 messages

MAC specific example



T_i	r_j	bid
1	1	10
1	4	9
2	2	7
3	1	6
4	3	5
5	5	4
6	7	3
7	6	2

Auction starts at price 11, falling 0,1 every ε. After10ε price is 10, T_1 sends "I take it", but r_1 is too far.10ε later, price is 9, and $T_1 \longrightarrow r_4$ fails: r_4 is "asleep". At price 7, $T_2 \longrightarrow r_2$ is set. 10ε later, r_1 declines $T_3 \longrightarrow r_1$ because it knows about $T_2 \longrightarrow r_2$. $T_5 \longrightarrow r_5$ and $T_6 \longrightarrow r_7$ are set. At price 2, r_6 declines $T_7 \longrightarrow r_6$ because of $T_6 \longrightarrow r_7$

MAC Implementation issues

- Distributed version requires a “common clock”, which may or may not be a major challenge
- Auctioneer (controller) can easily handle asynchronous terminals by announcing start, initial price and time-rate of decrease, and possibly broadcasting the new price at every “tick”
- Protocol parameters (initial price, rate of decrease, etc) should be “optimised”. Processing and signal travel time, clock “drift”, and “valuations” statistics should be considered
- Possibility of simultaneous “I-take-it” needs to be addressed

Possibility of “tied” winners

- If several “I take it” are simultaneously sent:
  - potential receivers won’t respond (unable to decode)
  - winners will ‘think’ receivers are unavailable
  - auction will continue
- Thus infrequent ties are harmless
- If the possible bids can be idealised as continuous random variables, then the probability of tied bids is negligible
- If bids depend on “channel state” the probability of consecutive ties by same terminals is negligible
- If valuations are “discrete”, say between 1 and M, then
  - at auction start, each terminal adds to “true” valuation a random number between $-\frac{1}{2}$ and $\frac{1}{2}$
  - probability that 2 terminals remain tied is negligible

Recapitulation

- Auctions have long been used, including in medium-access allocation
- Earlier proposals require a controller and an alternate MAC scheme for bidding
- The bidding protocol could
  - be resource-wasteful, if contention-free, or
  - miss important bids, if contention-based
- The Dutch auction is a solid foundation for MAC, because it
  - admits distributed (auctioneer-free) implementation among synchronised terminals
  - automatically and simply prioritises higher bids through its own built-in bidding protocol
  - exhibits exceptional signalling economy (in a single-channel scenario, only one bid signal is strictly necessary: the winner's)

Conclusion

- We have proposed and analysed *qualitatively* the application of the Dutch auction for medium access allocation, including in infra-structureless networks
- We conclude that our proposal:
  - retains the favourable features of previously proposals,
  - while remedying their most serious limitations, and
  - expanding the set of scenarios where MAC auctions can be used

THANK YOU !!!

Aalsmeer (NL) flower auction

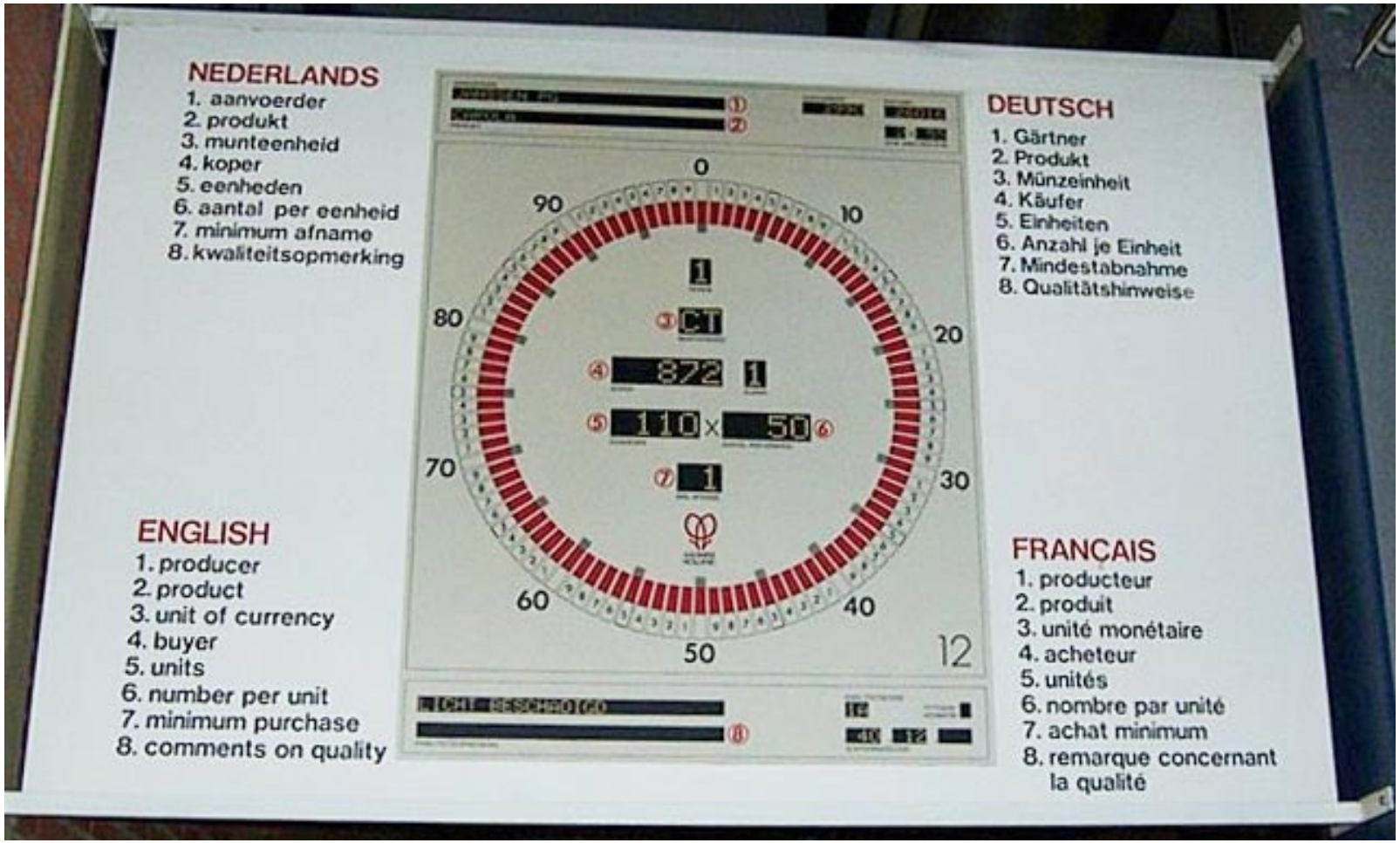
- Price clock starts at a “high” price, which progressively falls
- A bidder wishing to buy at current price, pushes a button to stop the clock, and uses microphone to indicate desired quantity
- Then the price clock moves to a slightly higher price, before resuming decreasing movement
- The next bidder who stops the price clock buys at current price, and so on until the complete lot of flowers is sold
- The auction then starts to sell another lot
- Prices form about once every 4 seconds on a clock

Facts and figures about Aalsmeer flower auction

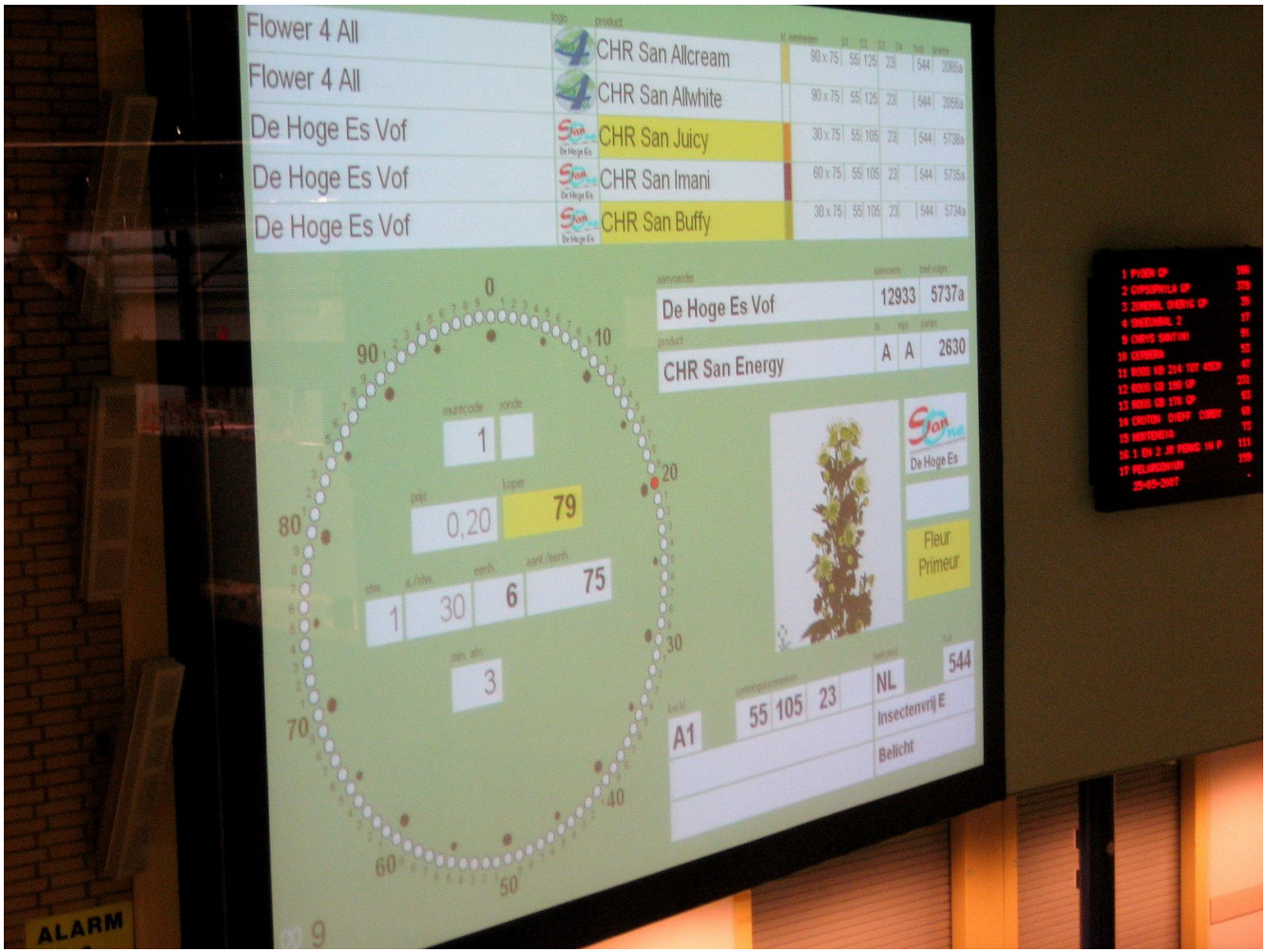
According to www.vba-aalsmeer.nl, in 2006 :

- Daily number of growers delivering products: ≈5.300
- Daily number of traders purchasing: ≈1.050
- Daily number of transactions: ≈44.000
- Transactions per clock per hour: ≈1.100
- Average daily turnover (auctioning): EUR 4,8 million
- Annual turnover: EUR 1,75 billion
- Size of auction complex: 1 million m^2 or 200 football fields (World's largest commercial building per Guinness)

Dutch clock (detailed view)



Dutch clock for image-based (remote) auctions



Dutch auction in progress

Aalsmeer, The Netherlands