Consumption Policies and Unifying Heterogeneous Resource Constraints

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Agenda

- Goals
  - Introduce the new Consumption Policy feature
    - Available as of HTCondor 8.1.2
  - Describe how it can aid in thinking about:
    - accounting group quotas
    - match costs
    - slot weights
- Topics
  - Partitionable Slots
  - Scheduler splitting (`CLAIM_PARTITIONABLE_LEFTOVERS`)
  - Consumption Policies
  - Examples
  - Unit analysis for slot weights and match costs

In the Beginning: Partitionable Slots

- “p-slots” for short
- Present aggregate compute resources
- Designed to service multiple jobs
- Negotiator matches one job per p-slot per cycle
- Consequences
  - p-slots required multiple cycles to load
  - SlotWeight expressions make p-slots expensive
    - Accounting group starvation

Accounting Group Starvation

- Default: SlotWeight = Cpus
- SlotWeight on a 32-core machine = 32
  - Therefore cost to match = SlotWeight = 32
- An accounting group with quota < 32 can never match that resource
- This problem becomes more exaggerated as cores increase
- gittrac #3013

CLAIM_PARTITIONABLE_LEFTOVERS

- AKA “scheduler splitting”
- Side-step negotiator cycle bottleneck
- Enable scheduler to match multiple jobs against a p-slot matched in the negotiator
- Limitations
  - P-slot matches still expensive to the negotiator
    - Accounting group starvation still possible
  - Doesn't play well with globally-accounted resources
    - Concurrency limits disrespected
  - Matched resources not accessible to jobs from other schedulers
    - p-slot unavailable to negotiator until startd updates -> collector
- Advantages:
  - Improved scalability, especially with multiple schedulers

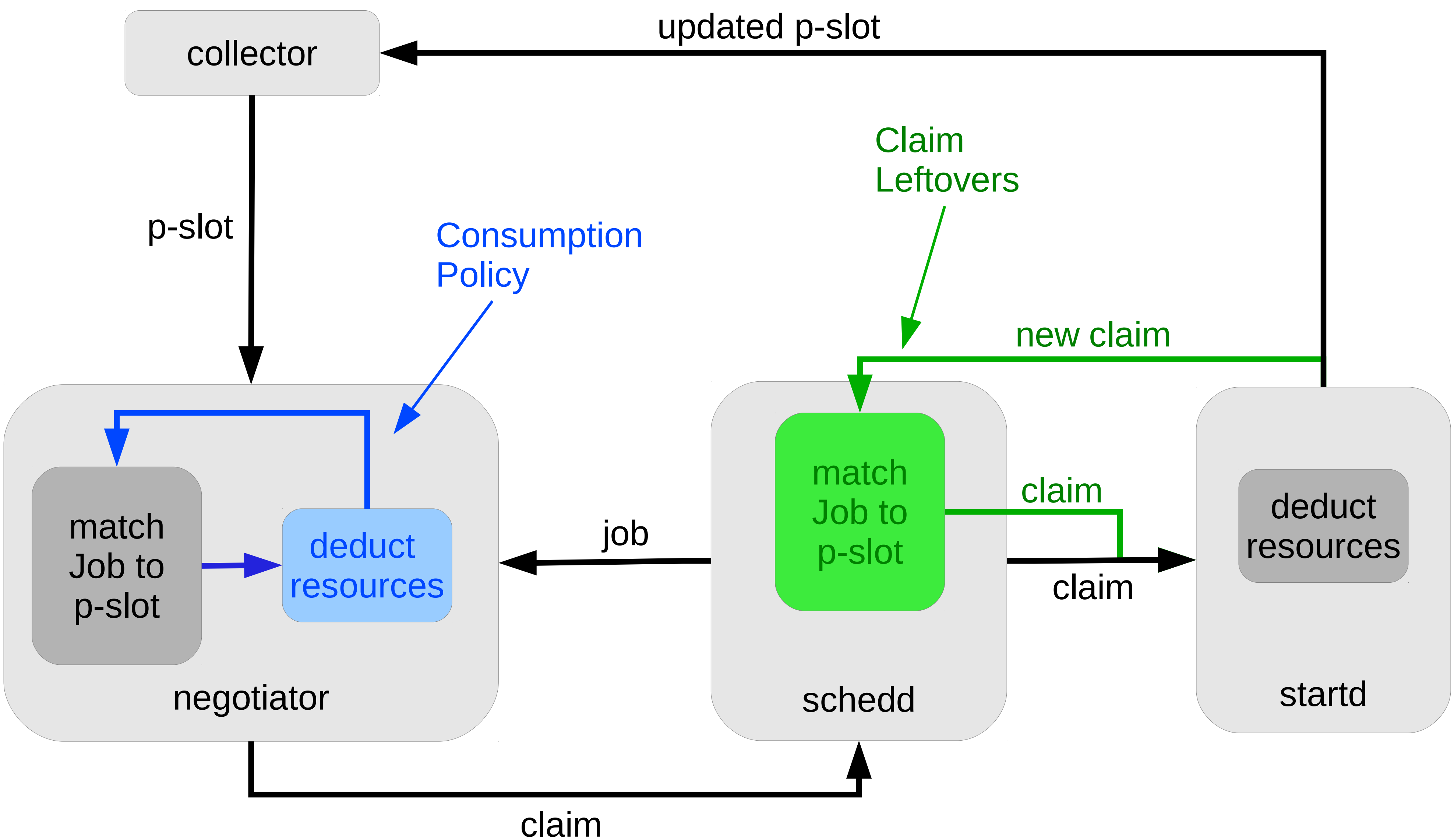
A Unit Analysis Question

- Suppose I have a pool where execute nodes advertise a mixture of slot weights:
  - `SLOT_WEIGHT = Cpus`
  - `SLOT_WEIGHT = Memory`
  - `SLOT_WEIGHT = Disk`
- When the negotiator computes the available resources by summing slot weights for all slots, what unit does that sum have?
- What unit do group quotas have?
- What does it mean to compare the cost of matching against one slot versus another?

Consumption Policies

- Resources consumed by a match between a job and a p-slot become a *configurable policy*
  - Expressions evaluated in context of p-slot resource classad
  - Special 'target' scope refers to candidate job classad
- Consumption Policy expressions reside on the p-slot classad
  - Available to startd claiming logic *and* negotiator matching logic
- Enable the negotiator to match multiple jobs against each p-slot in a single negotiation cycle

Matchmaking Flows



A Simple Consumption Policy

```
# Assumes a partitionable slot configuration

# Enable use of consumption policies
CONSUMPTION_POLICY = True

# Define a simple consumption policy:
# "target" refers to the scope of the
# candidate job classad
CONSUMPTION_CPUS = target.RequestCpus
CONSUMPTION_MEMORY = target.RequestMemory
CONSUMPTION_DISK = target.RequestDisk

# Traditional CPU-centric match cost
SLOT_WEIGHT = Cpus
```

Match Cost With Consumption Policies

Recall: the legacy match cost = SlotWeight

Match cost for a p-slot with a consumption policy is defined as reduction in slot weight after deducting resources used by a match:

1. Evaluate SlotWeight (W)
    1. W <-- SlotWeight = Cpus = 8
2. Evaluate ConsumptionXXX expressions for each resource
    1. UsedCpus <-- ConsumptionCpus = target.RequestCpus = 1
3. Subtract consumed resources from p-slot resources
    1. Cpus <-- (Cpus – UsedCpus) = (8 – 1) = 7
4. Re-evaluate SlotWeight (W')
    1. W' <-- SlotWeight = Cpus = 7
5. Match cost = W – W'
    1. Cost <-- (W-W') = (8 – 7) = 1

Reusing P-Slots in the Negotiator

- Evaluate candidate match cost w.r.t. consumption policy expressions on the p-slot
- If resource consumption is not feasible, match fails: remove p-slot from the list
  - Insufficient resources
  - Failed to evaluate to integer values >= zero
  - All consumption policies evaluated to zero
- If candidate match succeeds, subtract its resources and keep p-slot on the list
  - P-slot stays at front of list (depth-first loading)
- When slot weight drops to zero, remove from list

Pros and Cons

- Advantages
  - Negotiator can load p-slots in a single cycle
  - Concurrency limits respected
  - Jobs from multiple schedulers can match against a p-slot
  - Matches charged only for portion of resources used
    - Avoids accounting group starvation due to expensive p-slots
- Limitations
  - Negotiator bears cost of p-slot loading
    - Cannot scale out, as with scheduler splitting

Compatibility

- P-slots advertising a Consumption Policy can coexist with other slot flavors
  - P-slots having no consumption policy
  - Static slots
  - startds configured for `CLAIM_PARTITIONABLE_LEFTOVERS`
    - A startd cannot simultaneously enable consumption policies *and* leftovers
- Consumption Policies operate with extensible resources
  - A Consumption Policy expression must be declared for *every* resource, including extensible resources
    - All resources (including extensible) have default consumption policies
  - Not integrated with named (non-fungible) resources

Memory Centric Policy

```
CONSUMPTION_POLICY = True

CONSUMPTION_CPUS = target.RequestCpus
CONSUMPTION_MEMORY = quantize(target.RequestMemory, {128})
CONSUMPTION_DISK = quantize(target.RequestDisk, {1024})

# use of quantize() similar to MODIFY_REQUEST_EXPR_*

# synced with consumption expression
SLOT_WEIGHT = floor(Memory / 128)

# If total memory available is 1GB, then this
# slot + policy can support up to 8 matches, and
# total weight (prior to matching) is 8
```

Static Slot Policy

```
CONSUMPTION_POLICY = True

# consume all resources - emulate static slot
CONSUMPTION_CPUS = TotalSlotCpus
CONSUMPTION_MEMORY = TotalSlotMemory
CONSUMPTION_DISK = floor(0.9 * TotalSlotDisk)
# TotalSlotDisk != Disk even on an unused p-slot

# Slot supports exactly one match
SLOT_WEIGHT = 1
```

Multi-Centric Policy

```
CONSUMPTION_POLICY = True

# Either Cpus or Memory might be limiting
CONSUMPTION_CPUS = target.RequestCpus
CONSUMPTION_MEMORY = quantize(target.RequestMemory, {256})
CONSUMPTION_DISK = quantize(target.RequestDisk, {128})

# Define slot weight as minimum of remaining-match
# estimate based on either cpus or memory:
SLOT_WEIGHT = ifThenElse(Cpus < floor(Memory/256), Cpus,
floor(Memory/256))

# Behaves a bit like Dominant Resource Fairness, due
# to submitter being effectively charged for the resource
# that most reduced the available matches against the p-slot
# ("Dominant Resource Fairshare")
```

Observations

- Match cost is defined as: reduction of slot weight after deducting resources used for a match
- The slot weight expression governs the orientation of the policy
  - `SLOT_WEIGHT = Cpus`
  - `SLOT_WEIGHT = floor(Memory / 128)`
  - `SLOT_WEIGHT = floor(Disk / 1024)`
- It also embodies a definition of how many matches the p-slot supports
  - If total memory available is 1 GB, then slot can support up to 8 matches
  - equivalent to number of jobs serviceable

Unifying Heterogeneous Policies

- A p-slot's total slot weight is equivalent to the maximum number of matches it can support
  - i.e. Slot weights are in units of “matches”
  - This is true *regardless of policy orientation:* cpu-centric, memory-centric, etc
- Match cost = “reduction of slot weight” and is therefore in the same units: matches
- Assuming slot weights are enabled for matchmaking, then total resource assessment, and therefore accounting group quotas, are also in these same units
  - Particularly when configuring dynamic quotas
- **Therefore: Slot weights, match cost and group quotas can be modeled in the same unit: matches (aka jobs, aka claims)**
  - Furthermore, this unit analysis holds for pools combining p-slots having heterogeneous policy orientations

Future Development

- Non-integer resources
  - Model concepts such as sub-core jobs
- Integration with named (non-fungible) resources
  - GPUs
- Support breadth first p-slot loading
  - Currently, slots are loaded depth first

References

- http://research.cs.wisc.edu/htcondor/manual/v8.1/3_3Configuration.html#20322
- https://htcondor-wiki.cs.wisc.edu/index.cgi/wiki?p=ConsumptionPolicies
- http://erikerlandson.github.io/blog/categories/slot-weights/