Applying the P-Medians in the Design of Modern Systems-on-Chip

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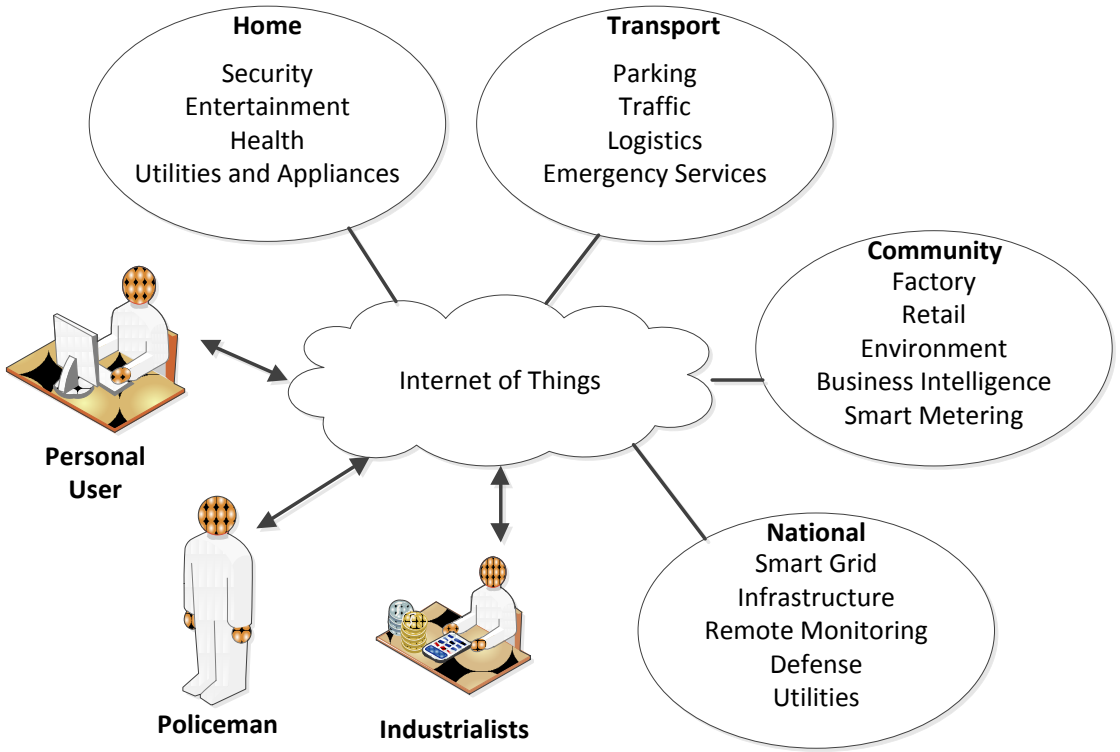
Devices for Internet of Things (IoT)

Architecture:

- **homogeneous**
- heterogeneous

Requirements:

- low energy consumption
- small area
- high speed of data transfer between chip's nodes and external devices



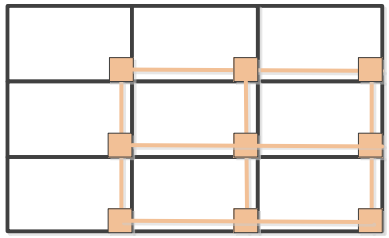
Development of new chip

It is important to arrange IP-blocks on chip according to requirements such as distance, throughput and etc.

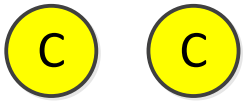
- if system contains several controllers accessing external memory
- if system is to communicate with different external interfaces such as PCIExpress, USB, HDMI and others
- if specialized IP-blocks are included in System-on-Chip (SoC)

The P-medians searching is useful!

Chip



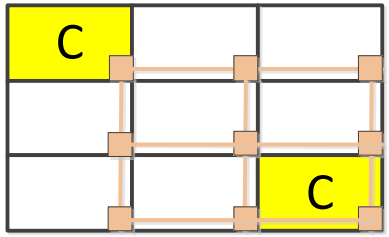
IP-blocks of external memory controlles

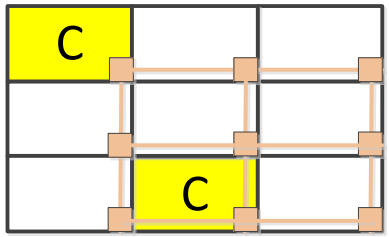


Distance requirement

2

Examples of arrangement





Methods for p-medians searching

	An approximate algorithm	**Method “traversing a path”**	**Direct tree search method**
Advantages	Low computational complexity	Theoretically and computationally attractive	Find all possible p-medians with the best answer
Disadvantages	Does not always give the best answer	Fail for some values of p	Time and memory consumption

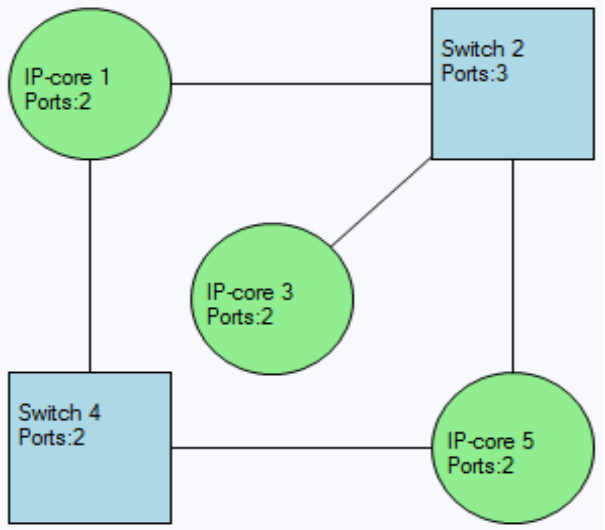
Criteria for p-medians search in SoC

To find p-medians with the following criterias:

1) Distance
2) Throughput
3) Load of P-medians
4) Support for multiple criteria

Algorithm for p-medians search (1)

1. Enter input data
   - Topology of SoC
   - Rules of routing
   - Number of medians (p=2)
   - Distance requirement (d=1)



2. Create matrix of minimal distance

	1	2	3	4	5
1	0	1	2	1	2
2	1	0	1	2	1
3	2	1	0	3	2
4	1	2	3	0	1
5	2	1	2	1	0

Algorithm for p-medians search (2)

3. Sort matrix of min distances according to distance requirement
   - All start nodes are **potential medians**
   - Nodes, which are marked in **red**, **will not be considered** (don't satisfy the requirement)
   - Nodes that are in the same column under the start node are **attachable** nodes

1	2	3	4	5 ← Start node
1_0	2_0	3_0	4_0	5_0
2_1	1_1	2_1	1_1	2_1 ← End node
4_1	3_1	1_2	5_1	4_1
3_2	5_1	5_2	2_2	1_2
5_2	4_2	4_3	3_3	3_2

Distance from start node to end node

4. Create median set Mm and add P potential medians to Mm

   For example, Mm={1,2}

Algorithm for p-medians search (3)

5. Create not median set Mn
6. For each node in Mm:
   - If a node from attachable nodes set doesn't exist in Mm or Mn then this node is added to Mn
   - Sum distance from median node to not median node

1	2	3	4	5
1_0	2_0	3_0	4_0	5_0
2_1	1_1	2_1	1_1	2_1
4_1	3_1	1_2	5_1	4_1
3_2	5_1	5_2	2_2	1_2
5_2	4_2	4_3	3_3	3_2

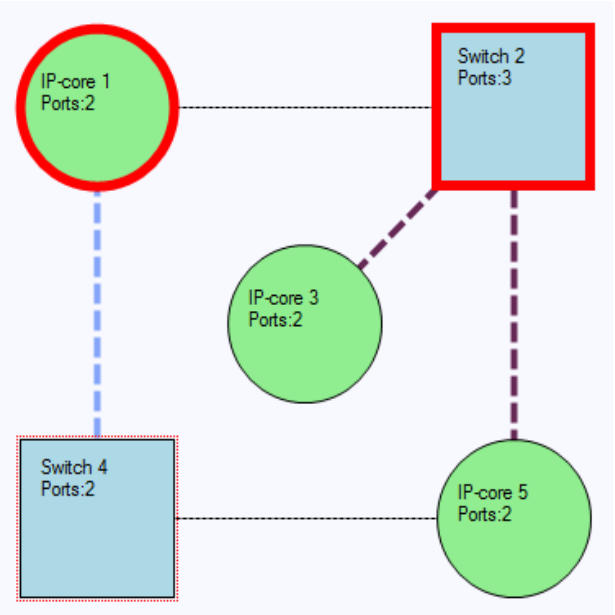
For example, Mm={1,2} Mn={3,4,5} sum =3

7. If Mm and Mn cover the total set of nodes in the graph G then solution is added to solutions set

$$Mm \cup Mn = G$$

8. Result solution is the one with minimal sum value

Solutions



Input data:

P=2

D=1

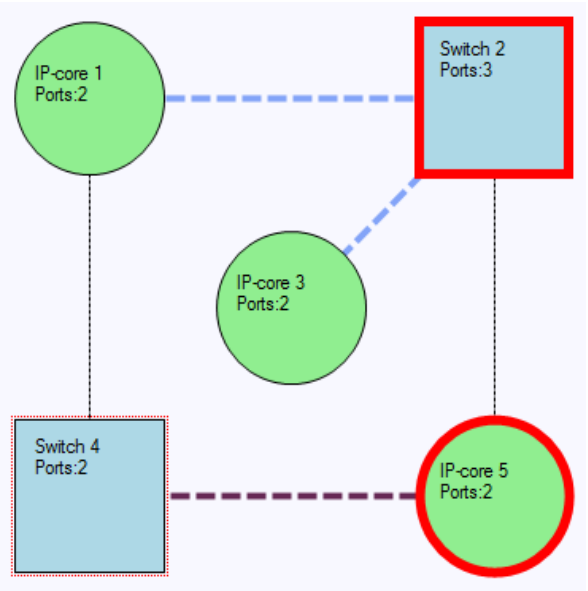
Output data:

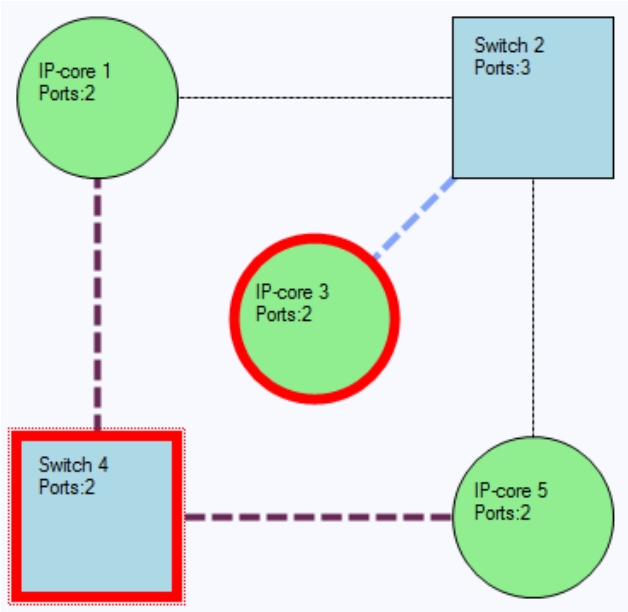
Sum=3

Mm={1,2} Mn={4,3,5}

Mm={2,5} Mn={1,3,4}

Mm={3,4} Mn={2,1,5}





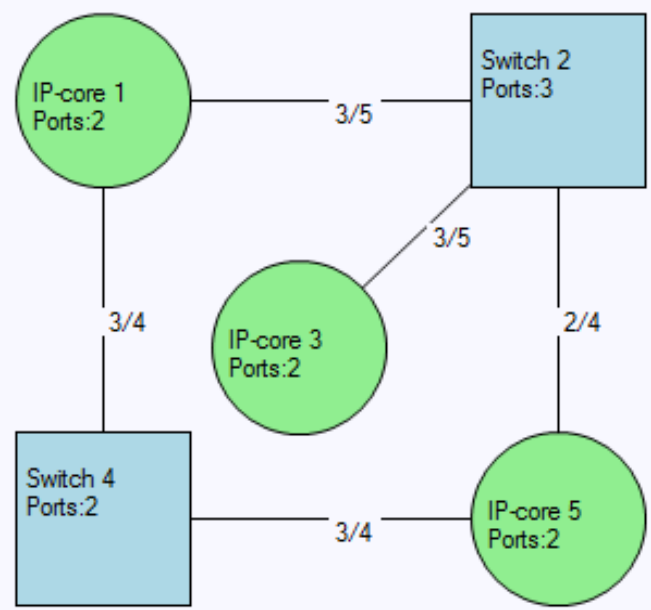
Throughput criteria in p-medians search

Algorithm is the same as the algorithm with limit on distance

Matrix of minimum throughput is used instead of distance matrix

Matrix of min throughput:

	1	2	3	4	5
1	0	2	2	1	2
2	2	0	2	1	2
3	2	2	0	1	2
4	1	1	1	0	1
5	2	2	2	1	0

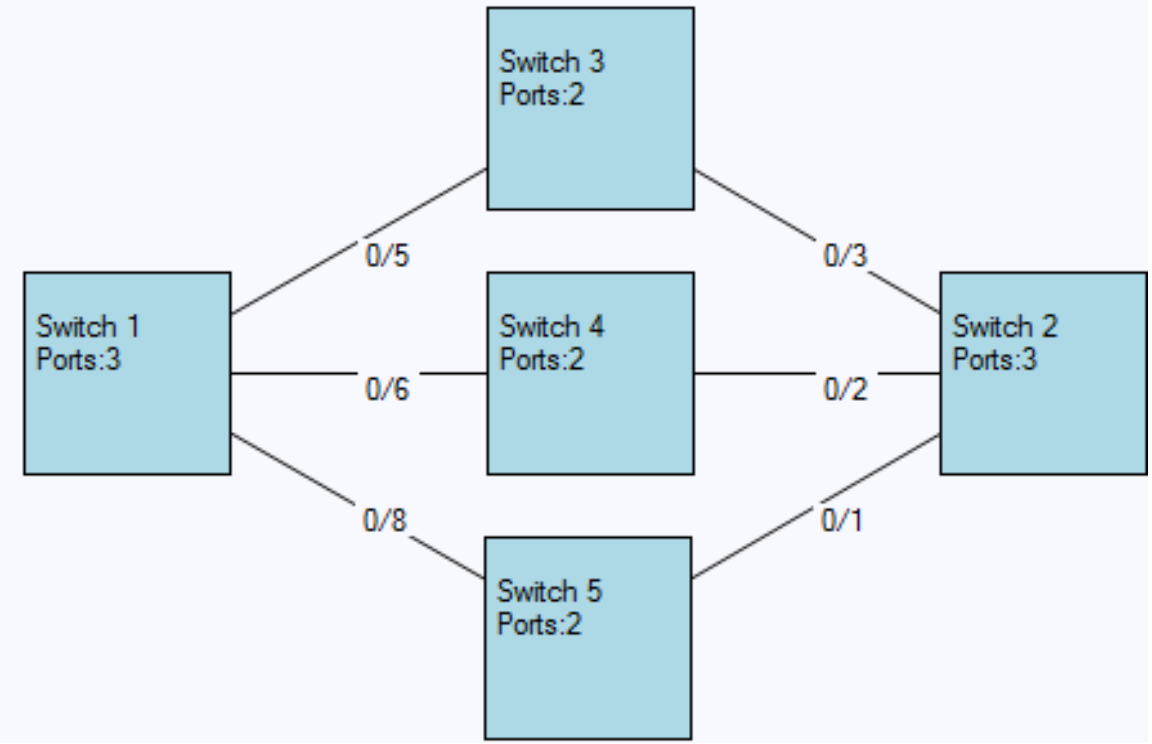


Link represented as [link load] / [link throughput]

Throughput matrix creation

Throughput is minimum value of links throughputs from shortest route

If there are several shortest routes, minimum value of throughput is found for each route. Maximum value is used.



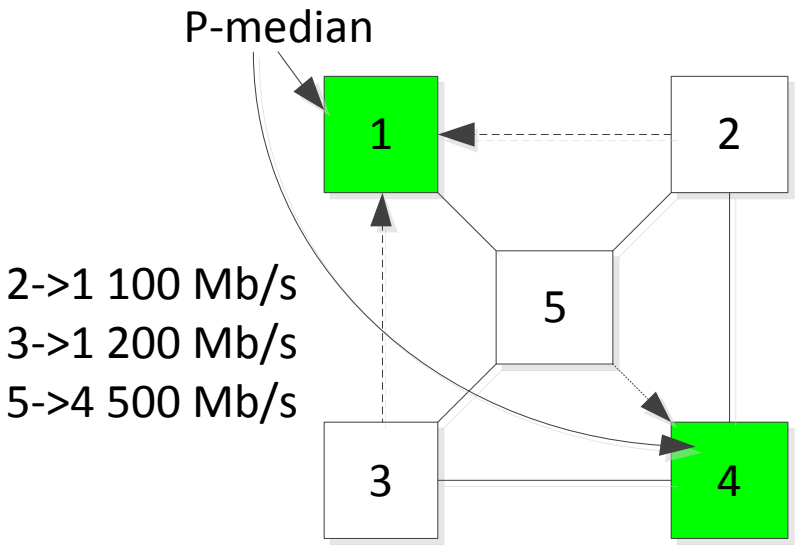
Route 1: 1-3-2, $Thr_{min\_1}=3$
Route 2: 1-4-2, $Thr_{min\_2}=2$
Route 3: 1-5-2, $Thr_{min\_3}=1$

$Tthr_{1,2}=max\{Thr_{min\_i}\}$

$Thr_{1,2}=3$

Load requirement

Load is analyzed after getting solutions with distance and/or throughput limit



Load of system = 800 Mbit/s
Load of 1 node = 300 Mbit/s
Load of 4 node = 500 Mbit/s
Average load of node = 400 Mbit/s

Delta load of 1 node = -100 Mbit/s
Delta load of 4 node = +100 Mbit/s

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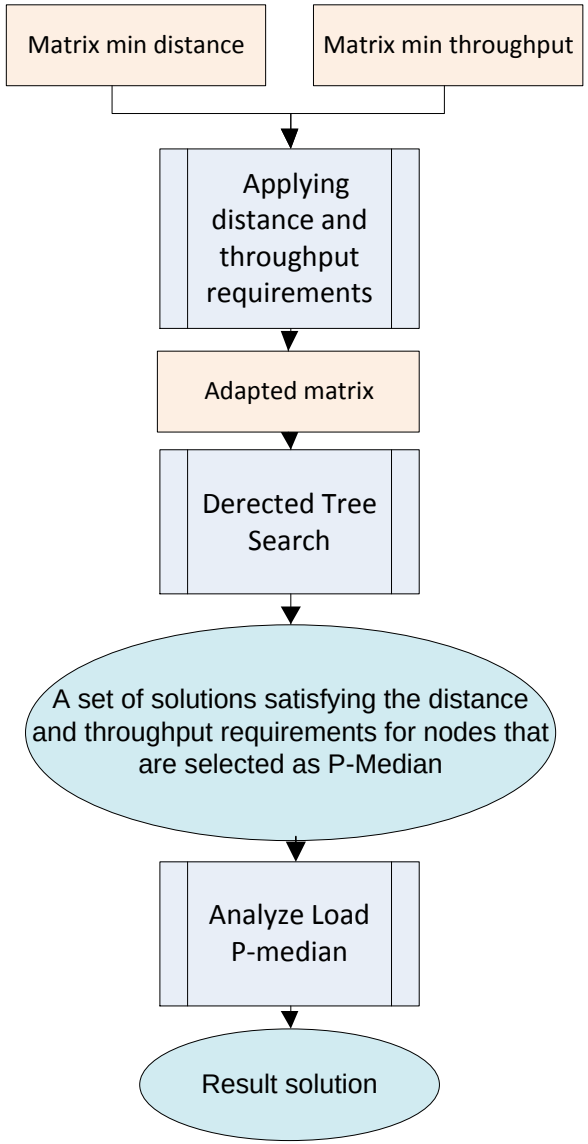
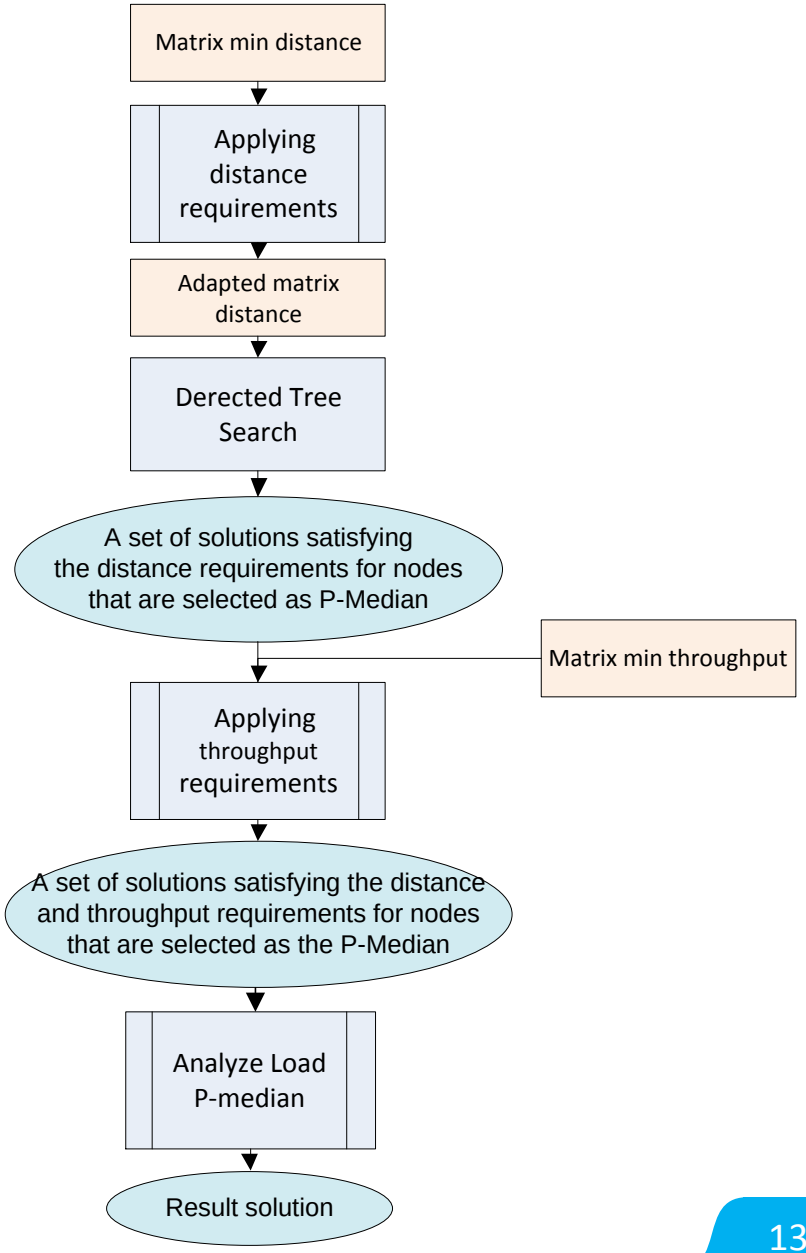
Developer

Multiple criteria in p-medians search





Conclusion

Described method of directed tree search:

- For any value of P
- Always gives the best solution

Using p-medians for nodes allocation:

- Searching for components position on chip according to requirements (distance, throughput, load and etc.)
- It is possible to use several criterias together

Future work

1. Create methodology for searching for p-medians of other types
2. Analyze energy consumption
3. Add different routing algorithms