By jointly considering the caching capacity of each ONU-BS as well as the maximum capacity of PON, the throughput optimization problem is formulated as a mixed-integer programming (MIP) expressed as follows.

P1:

|  |  |
| --- | --- |
|  | (14a) |

s.t.

|  |  |  |
| --- | --- | --- |
|  | | (14b) |
|  | (14c) | |
|  | | (14d) |
|  | (14e) | |
|  | | (14f) |

Constraint (14b) guarantees that for each *ONU-BSn*, the sum of the power consumed by wireless signal transmission, caching and the circuit should not exceed the maximum power limitation. Constraint (14c) means that the requested transmission rate of the files which are not be cached by all ONU-BSs to the core network should not exceed the channel capacity constraint of PON. Constraint (14d) makes sure that for each *ONU-BSn*, the total number of bits of the cached files should not exceed its maximum caching capacity. Constraint (14e) guarantees that for each *UEj*, its assigned wireless transmission rate by ONU-BS should not be lower than its minimum receiving rate limit, in order to guarantee its QoS.2

Let

|  |  |
| --- | --- |
|  | (20) |

In the case of Problem P1, we have

The Lagrangian of P1 can be given as

|  |  |
| --- | --- |
|  | (18) |

where , ∈ (i = 1, 2, 3) are Lagrangian multipliers.

Obviously,

|  |  |
| --- | --- |
|  | (21) |

which represents that when the allocated wireless transmit power is considered as an independent variable, the objective function of Problem P1 is decreasing and strictly concave. Justified by the same reason, is also a concave function.

Considering the synthesis constraints from the bearer capacity of feeder fiber, the caching capacity of ONU-BS, and the QoS requirements of UE, it can be proved that < 0 , i = 1, 2, 3.

The KKT Conditions of Problem P1 is expressed as

We denote the solution space of problem P1 by A, thus we have that

|  |  |
| --- | --- |
|  | (22) |

We denote the element of A as , which represents a pair of caching file selection and wireless power allocation schemes that acts on network throughput. Let denotes whether is chosen to be the solution, where we have . More specifically, means that is chosen to be the solution and vice versa.

Let to be the backhaul bandwidth occupied by *ONU-BSn* with respect to solution , where we have

|  |  |
| --- | --- |
|  | () |

Likewise, deﬁne to be the sum rate of UE associated to *ONU-BSn* with respect to solution , where we have

|  |  |
| --- | --- |
|  | () |

Then problem P1 can be converted into the problem of determining the value of with the aim to maximize the downlink wireless access throughput of the B5G WOBAN as follows,

P2:

|  |  |
| --- | --- |
|  | () |

s.t.

|  |  |
| --- | --- |
|  | () |
|  | () |
|  | () |