

The following sections focus on the D2D downlink transmission of a single-cell marine time communication system, which has an onshore BS equipped with  antennas and  single-antenna users (ships) in the sea. We assume that the subcarrier bandwidth is , and the total bandwidth of  subcarriers is .

In the studied system, D2D communications between ships use the same licensed band of cellular network, and the same air interface of the underlying cellular communication. As a result, D2D communications consumes part of the resources allocated to the cellular network, i.e., D2D communications also use the  subcarriers whose bandwidths are . Given a time slot, each D2D or cellular transmission link will use distinct subcarrier.

Without loss of generality, we assume the cell shape to be a semicircle with radius . Each user sails into and out of the cell according to its shipping lane and timetable. For each user, delay-torrent service is assumed, and the total amount of the data required by the  user is denoted by . In order to simplify the problem, we only consider D2D and cellular communications of the ships in the semicircle. We also assume all the users request different data and the system has no D2D data reuse.

We further assume a modified 2-ray propagation model, since the sea surface is relatively flat. For a given subcarrier, we denote the composite channel gain from the BS/relay  to the user  at time slot  by . The small-scale fading vectors  follows a complex Gaussian distribution with standard deviation , i.e., . The large-scale fading coefficient  is expressed as

 (1)

where  is the carrier wavelength,  is the distance between the BS/relay  and the user  at time slot . The antenna height of the transmitter and the receiver are represented by  and  respectively.